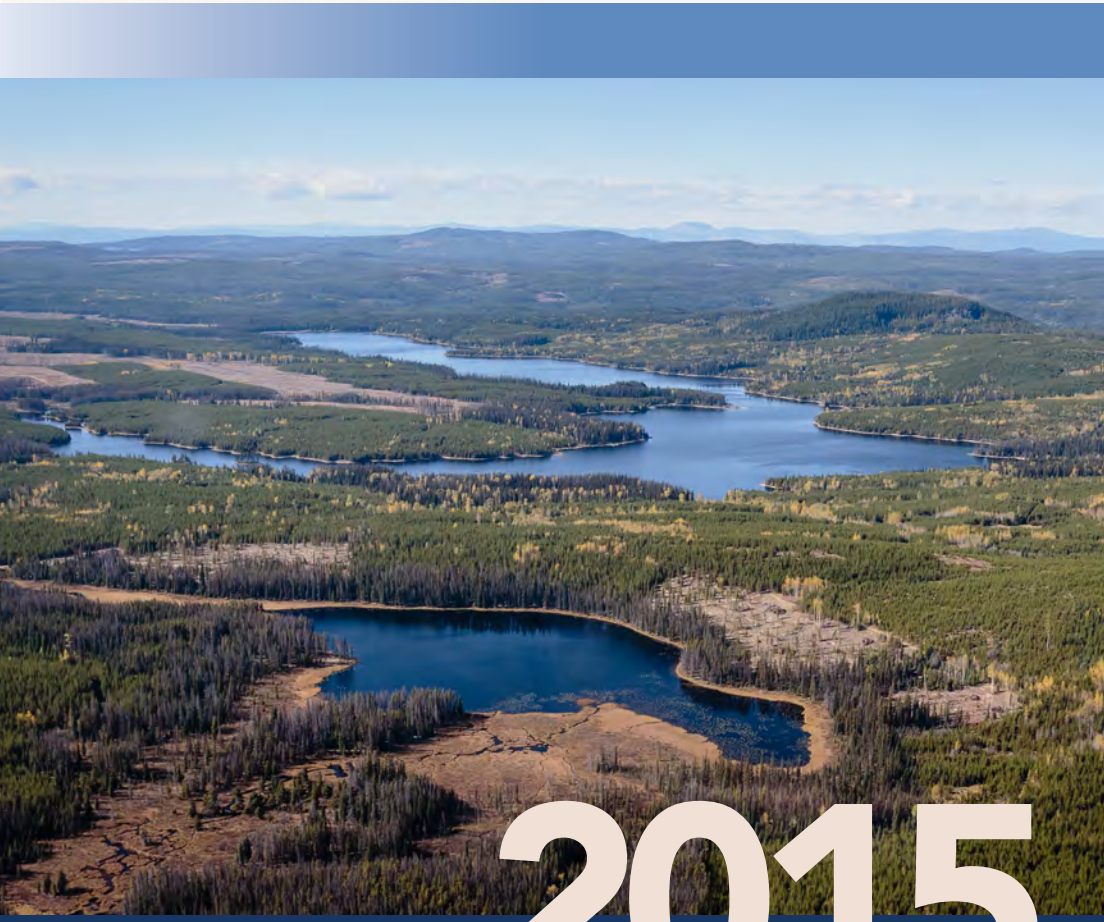
4th INTERNATIONAL CONFERENCE

FORESTS AND WATER IN A CHANGING ENVIRONMENT

KELOWNA, BC, CANADA | JULY 6 - 9, 2015



2015 PROGRAM GUIDE

a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

IUFRO

4th IUFRO International Conference on Forests and Water in a Changing Environment
Kelowna, British Columbia, Canada
6-9 July 2015

Cover Photo: Aberdeen Plateau east of Vernon, British Columbia (Barbara Zimonick)

Welcome from the Conference Co-Chairs

Dear Friends and Colleagues,

Welcome to the 4th IUFRO International Conference on Forests and Water in a Changing Environment.

As we know, forests play a vital role in sustaining water resources and aquatic ecosystems. Forest disturbance, both natural (e.g., wildfire, insects, disease, windstorms, drought) and human (e.g., timber harvesting, land conversion) caused, can have a profound effect on hydrologic, geomorphic and ecologic processes. With climate change, natural disturbances are becoming more frequent and catastrophic. This, together with growing human disturbance, will undoubtedly affect water resources and have significant implications for land managers and policy makers. Our understanding of hydrologic and ecologic responses to accelerated environmental and land use change is key to the development of adaptive and mitigating strategies ensuring the continued security of water supplies and ecological values.

Building on the success of past IUFRO Forests and Water conferences (Beijing in 2006, Raleigh, NC in 2009, and Fukuoka in 2012), the fourth conference will focus on forest disturbance and hydrological processes in a changing environment.

We would like to take this opportunity to thank all of you for participating in this important conference. We also extend our sincerest appreciation for the generous support of our sponsors, and the efforts and hard work of the technical committee, the local organizing committee, and our volunteers, all of whom have made this conference possible.

Adam Wei
University of British Columbia Okanagan

Rita Winkler
British Columbia Ministry of Forests, Lands and Natural Resources Operations

Welcome from the International Union of Forest Research Organizations (IUFRO)

As president of IUFRO, it gives me great pleasure to welcome you to this 4th IUFRO International Conference on Forests and Water in a Changing Environment. This meeting treats one of the most important aspects of forestry and perhaps one that is often overlooked by those outside our field. It is widely recognized by world leaders, both political and from the scientific community, that water is one of our most threatened resources. It is important to remember that approximately 800 million people lack access to safe water, and this is especially true for my home continent – Africa. These are important messages that we must spread beyond the pillars of our research domains.

As a delegate attending this meeting, you well know that forests play a crucial role in sustaining clean water and various other watershed ecosystem functions. However, this role is negatively affected by growing pressures, such as various forms of forest disturbance and impacts of climate change. It is thus fitting that this conference will focus on forest disturbance and hydrological processes in a changing environment. This is also consistent with the IUFRO 2015-2019 Strategy that includes a focus on several knowledge gaps and uncertainties related to forests, soils and water. In particular, the impacts of climate change, forest management and soil conservation on water supplies.

IUFRO is the World's Network for Forest Science with more than 700 member organizations in 110 countries, representing between 15 000 and 20 000 forest researchers worldwide. As such, the organization plays a crucial role in promoting research in virtually all disciplines relating to forests and forestry. It is fitting that this important meeting focuses on the role that forests play in issues relating to the long term security of water supplies, integrating with one of our newly approved Task Forces that will develop a range of activities on this theme.

Thank you for attending this meeting, and I wish you an interesting, productive and enjoyable congress. I look forward to hearing of the many important outcomes that are sure to emerge.

With best regards,

Mike Wingfield
IUFRO President

On behalf of my Council colleagues and the citizens of Kelowna, I welcome delegates to the 4th IUFRO International Conference on Forests and Water in a Changing Environment.

Kelowna is an apt city to host such a conference, given our unique ecological nature – an arid climate with a watershed that is constantly under pressure. Our history of logging and wood product manufacturing also provides us with insights into forest stewardship practices.

The City of Kelowna is committed to leading in the development of a safe, sustainable and vibrant city. A key component of that development is our beautiful and fragile environment.

More than 90 per cent of vacant land within the City of Kelowna boundaries is protected from development, either because it is in the Agricultural Land Reserve, is environmentally sensitive or is in steeply sloped terrain.

The City of Kelowna has been purposeful about protecting our environment, as one of the first communities in British Columbia to introduce residential and commercial water meters to reduce water consumption.

To protect from further urban sprawl, our citizen-driven Official Community Plan introduced a permanent growth boundary to identify the land use limits for development.

Recent City of Kelowna land purchases will allow realignment of a portion of Mission Creek to its more natural meander, which will improve kokanee trout habitat and flood control.

As a city, we are always open to opportunities to protect or improve the spectacular natural environment we have here. I want to thank the organizers and delegates for bringing the vital subjects discussed at this conference to the attention of other levels of government and the scientific community.

Colin Basran
Mayor of Kelowna

a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

On behalf of the University of British Columbia, welcome to the wonderful UBC Okanagan campus. We are absolutely delighted to play host to the 4th IUFRO International Conference on Forests and Water in a Changing Environment. The Okanagan is a most appropriate setting for a discussion of natural and human disturbance of forests and the related consequences for water and other natural systems, given the region's rapid development, forestry industries, and other challenges such as wildfire and the mountain pine beetle. Moreover, the Okanagan is home to many outstanding researchers and government scientists specializing in understanding ecological systems and their resilience. Thank you to all those contributing to this important discussion. I wish you a very successful conference.

Professor Deborah Buszard
Deputy Vice-Chancellor and Principal

The Syilx People of the Okanagan Nation are a trans-boundary tribe separated at the 49th parallel by the border between Canada and the United States. Our Nation is comprised of seven member communities in the Southern Interior of British Columbia: Okanagan Indian Band, Osoyoos Indian Band, Penticton Indian Band, Upper Nicola Band, Upper and Lower Similkameen Indian Bands, and Westbank First Nation; and in Northern Washington state, the Colville Confederated Tribes (CCT). Our members share the same land, nsyilxcən language, culture, and customs. We are a distinct and sovereign Nation.

The Syilx People have always governed our land according to principles that are embedded in traditional knowledge, stories, teachings, ceremonies, medicines, dances, and the arts. These principles carry with them a sacred, inherent responsibility to care for the tmxʷulaxʷ (Our Land).

Nxʷə lxʷəltantə t describes the Okanagan People's relationship to the tmxʷulaxʷ as "that which gives us life."

The Syilx People feel a deep connection with our land and with our relatives, the animals and the trees, the rocks and all living things that share the environment. Our native *nsyilxcən* language grew out of our relationship with the land and the natural resources that surround us.

Our traditional stories reflect this deep connection and help to pass cultural, spiritual and historical knowledge down through the generations.

Today the people of the Okanagan nation continue to hunt and fish, to pick berries and dig roots in the territory of our ancestors. Our nsyilxcən language and our Syilx culture respectfully honour the natural laws of the tmixʷ – That which gives us life.

For More Information Visit

www.okanagannation.com

Schedule Overview

05-July			
14:00-20:00	Registration（EME upper mezzanine）		
18:00-20:00	ADM Sunshine Cafeteria open for dinner (Not covered by conference)		
06-July			
07:00-09:00	Breakfast (ADM Sunshine Cafeteria)		
07:00-10:00	Registration / Poster Setup (EME upper level and foyer)		
10:00-11:00	Opening Ceremony (ASC 140)		
11:00-12:00	**Keynote Talks I (ASC 140)**		
12:00-13:00	Lunch (ADM Sunshine Cafeteria)		
13:00-14:30	**Keynote Talks II (ASC 140)**		
14:30-15:00	Coffee break (ASC foyer)		
15:00-16:30	**Keynote Talks III (ASC 140)**		
16:30-18:00	Poster Session (EME lower foyer)		
18:00-20:00	Reception (EME lower foyer)		
19:00-20:00	Young Scientists Salon (EME upper mezzanine)		
07-July			
07:00-08:00	Breakfast (ADM Sunshine Cafeteria)		
08:30-10:10	**Session A1**: Disturbance and hydrology: Water quantity (EME 0050)	**Session B1**: Climate, forest changes and hydrologic responses: Forest stand scale (EME 1121)	**Session C1**: Applications of new methods and technologies (I) (EME 1151)
10:10-10:40	Coffee break (EME upper mezzanine and lower foyer)		
10:40-12:00	**Session A2**: Disturbance and hydrology: Methods (EME 0050)	**Session B2**: Climate, forest changes and hydrologic responses: Small watersheds (EME 1121)	**Session C2**:Applications of new methods and technologies (II) (EME 1151)
12:00-13:30	Lunch (ADM Sunshine Cafeteria)		
13:30-15:10	**Session A3**:Disturbance and hydrology: Water quality (EME 0050)	**Session B3**: Climate, forest changes and hydrologic responses: Large watersheds or regions (EME 1121)	**Session C3**: Applications of hydrological models (EME 1151)

Schedule Overview

15:10-15:40	Coffee break (EME upper mezzanine and lower foyer)		
15:40-17:00	**Session A4**: Disturbance and hydrology: Water quality and aquatic biology (EME 0050)	**Session B4**: Climate, forest changes and hydrologic responses: Continental scale (EME 1121)	**Session C4**: Forest carbon and water (I) (EME 1151)
Lake Cruise	Depart UBC-O 17:15 from parking lot E; pick-up at 21:00		
Vines and Wines	Depart UBC-O 17:15 from parking lot E		
18:00-20:00	ADM Sunshine Cafeteria open for dinner (Not covered by conference)		
08-July			
07:00-08:00	Breakfast (ADM Sunshine Cafeteria)		
08:30-10:10	**Session A5**: Reforestation and hydrological processes (I) (EME 0050)	**Session B5**: Watershed assessment and planning (I) (EME 1121)	**Session C5**: Forest carbon and water (II) (EME 1151)
10:10-10:40	Coffee break (EME upper mezzanine and lower foyer)		
10:40-12:00	**Session A6**: Reforestation and hydrological processes (II) (EME 0050)	**Session B6**: Watershed assessment and planning (II) (EME 1121)	**Session C6**: Surface water - groundwater interactions (EME 1151)
12:00-13:30	Lunch (ADM Sunshine Cafeteria)		
13:30-15:10	**Session A7**: Reforestation and hydrological processes (III) (EME 0050)	**Session B7**:Watershed assessment and planning (III) (EME 1121)	**Session C7**: Watershed hydrology assessments (EME 1151)
15:10-15:40	Coffee break (EME upper mezzanine and lower foyer)		
15:40-16:10	**Keynote Talk IV** (EME 0050)		
16:10-17:30	Closing Ceremony (EME 0050)		
19:00-21:00	Banquet at Laurel Packinghouse, downtown Kelowna; buses depart parking lot E at 18:15		
09-July			
Forests and Water Tour: Depart promptly at 07:30 from parking lot E			

Special Events and Field Trips

Student Awards

Awards will be available for the best student poster and student presentation. The awards will be presented at the banquet on Wednesday evening.

Monday 6 July Reception and Young Scientists Salon

A reception will be held to coincide with the poster session in the EME lower foyer. Drinks and light refreshments will be served. A fun, networking event for graduate students and early career scientists will be held in the EME upper mezzanine between 7 and 8 pm, coordinated by Dr. Jessie Tu and Christine Mettler.

Tuesday 7 July Okanagan Lake Dinner Cruise

Pre-registration required. Experience beautiful Okanagan Lake on a catered dinner cruise on The Lake Lounge. Buses will leave from Parking Lot E at **5:15 PM** (please be there 15 minutes early) to take participants to the waterfront in downtown Kelowna. The bus will leave downtown Kelowna at **9:00 PM** to return to the university. The same location will be used for drop off and pick up.

Tuesday 7 July Vines and Wines Tour

Pre-registration required. Buses will leave from Parking Lot E at **5:15 PM (**please be there 15 minutes early) for this organised evening tour on the Eastside Bench overlooking Okanagan Lake. See the vineyards, learn about production, and taste award-winning wine while enjoying canapés made from local, organically grown ingredients.

Wednesday 8 July Banquet

The final banquet will be held at the historic Laurel Packinghouse in Kelowna's Cultural District. Buses will pick up participants at the **Four Points Sheraton Hotel at 5:50 pm**, and leave **Parking Lot E at 6:15 PM** (please be there 15 minutes early). Buses are scheduled to leave the Laurel Packinghouse at **9:15 PM, 10:00 PM and 11:00 PM**, allowing participants the opportunity to enjoy downtown after the banquet. The same location will be used for drop off and pick up.

Thursday 9 July Post-Conference Tour

Pre-registration required. The bus will leave **Parking Lot E at 7:30 AM** and return at approximately 10:00 PM. The tour begins with a visit to the historic Myra Canyon Trestles and a short 2 km hike along the trestle trail (please bring good footwear). After a scenic drive, lunch will be provided at the Upper Penticton Creek Experimental Watershed. The return drive to Penticton will provide opportunities to see operational logging, municipal storage reservoirs and spectacular views of the Okanagan valley. The tour will end at the Poplar Grove winery where we will learn about grape production in a water-limited environment. Dinner will include Okanagan wine and food pairings.

General Information

Emergency Numbers

Emergency (fire, police and ambulance): dial 911
Reporting an on-campus incident: 250-807-9236
Campus security: 250-807-8111

Climate

Kelowna is spoiled with clear skies and low humidity during summer months, with temperatures ranging from 15-30°C (59-86°F). There is little precipitation, however thunderstorms can form due to high temperatures.

Navigating Campus

Maps of UBC Okanagan can be found online at: **maps.ok.ubc.ca/map**

Internet

There is free wifi on campus under "UBCVisitor" which requires only an e-mail to sign in. There is an activity time-out for this network, but signing back in is fast and easy.

If you are staying in the student residences, the studio, 1-bedroom suite, and family suites have wifi. The 4 bedroom apartments and single rooms do not have wifi, however an Ethernet cord to connect to the Internet is supplied in every room.

Transportation

There is a free shuttle bus to the airport from the Sheraton Four Points Hotel and the University of British Columbia-Okanagan. For more information inquire at the hotel's front desk.

Taxis

There is an app for Android and iPhone cellular devices called 'Kelowna Cabs' which you can download to book a cab in advance. Otherwise call:

Checkmate Cabs 250-861-1111 **Kelowna Cabs 250-762-2222**

Parking: **parking.ok.ubc.ca**

If a guest is living on campus for the conference, parking is $3.15/day per car/bus. These are special prices for the conference so be sure to pick up a parking pass at the front desk of the Nicola Residence Building when checking in.

For guests living off campus, parking is available in a variety of lots at different prices depending on proximity to the heart of campus. In some lots, parking is restricted to afternoons and evenings only. Please follow the instructions posted in each parking lot.

Public Bus **bctransit.com/kelowna/home**

Day Rate: $6.00 **Cash Fare: $2.25**

There is a bus loop on University Drive in front of the Engineering, Management, and Education Building (EME). Schedules are posted on the bus

shelters, but there is also an app for Android and iPhone cellular devices called 'Transit App' which you can download to find bus routes and travel options.

The express bus to **Orchard Park Mall** and **downtown** is the number **97**. It comes every 20-30 minutes until midnight on weekdays and Saturday, and until 11:00pm on Sunday.

The number **8** bus will drive you through **Rutland** and to **Orchard Park Mall**. It travels every 20-30 minutes on weekdays from 6:00am to 9:00pm, and then every hour until midnight. On Saturdays, the bus starts at 7:00am, traveling every 30-60 minutes until 1:00am. On Sundays, the bus starts at 8:00am coming every 45-60 minutes until 11:00pm.

The number **23** bus will take you around **Lake Country** (north of UBCO). It comes every 20-30 minutes starting at 5:30am to 1:00am on weekdays. On Saturday, it starts at 7:00am and comes every hour until midnight. On Sunday it starts at 8:00am and comes every hour until 10:00pm.

Other bus routes are described on the app and at some bus terminals. Ask any bus driver for a printed bus schedule.

Car Rentals

If you want to rent a car for the weekend, there are four car rental agencies at the Kelowna airport, with desks in the main terminal building near arrivals.

Avis
250-491-9500

Budget Car and Truck Rentals
250-491-7368

Enterprise Rent-a-Car
250-491-9611

National Car Rental
250-765-2800

Where to Eat

On campus:

There is a Starbuck's Coffee Company on the lower level of the Fipke Building (FIP), and Tim Horton's coffee shop on the main floor of the Library.

If you are tired from your long day and want a quick bite to eat, the Sunshine Cafe will serve dinner from 6:00pm to 8:00pm on July 5. The Sunshine Cafe is located on the west side of campus in the Administration Building (ADM), past the bookstore on the second floor.

If the set dinner time at the Sunshine Cafe does not work with your schedule, below are some restaurants that **deliver takeout**.

Okanagan Pizza
250-765-5551

Olympia Greek Taverna
250-765-0484

Imperial Banquet
250-765-1129

Mon Thong Thai Food Restaurant
250-860-6809

Off campus:

If you want to get out of your room and explore Kelowna's diverse restaurant scene, below are several options.

Ric's Lounge and Bar (at the Four Points Hotel, a 15 minute walk from UBC-O)
5505 Airport Way
(250) 807-7427

Bluetail Sushi Bistro
102-1675 Commerce Ave
(778) 484-5900

Bordello's Italian Pizzeria
1481 Water Street
(250) 868-0466

Yamato
2575 Highway 97 N, Suite 1
(250) 762-2618

Freddy's Brew Pub
948 McCurdy Rd
(250) 765-8956

Fast Food Locations

McDonalds
2120 Harvey Ave

A&W
2112 Harvey Avenue

Masala Fusion Indian Cuisine
103 - 2106 Harvey Avenue
(250) 317-3737

Joey's Kelowna
300-2475 Highway 97
(250) 860-8999

White Spot Family Restaurant
2190 Harvey Ave
(250) 763-1660

Asian Pear Buffet
2050 Harvey Ave
(250) 868-0038

Poppadoms – Taste India!
948 McCurdy Rd
(778) 753-5563

The Italian Table
2402 Hwy 97 N
(250) 979-6930

Tim Hortons (Canadian sandwich and coffee shop)
1694 Powick Rd

Subway
100 1640 Leckie Rd

Electronics

Kelowna uses the same electrical current and plug shape as the United States (110 volts AC at 60Hz). Oversea adapters should be brought or can be bought at Wytek Direct.

Wytek Direct
#136-1735 Dolphin Avenue
250-861-1989
Monday to Friday 8:30 AM to 5:00 PM
Saturday 10:00 AM to 2:00 PM
Closed on Sunday

Currency and Banking

The Canadian Dollar is the currency of exchange, but U.S. Dollars are also accepted at many points of sale.

Most bank machines offer Plus, Cirrus, and Interac service. There are three automated teller machines (ATMs) on campus. Two are in the University Centre (UNC) building: one inside the student bar (The Well), and the other in the food court on the bottom floor. A third ATM is located in the Administration (ADM) building, just outside the Sunshine Cafe.

Shopping

There are two main shopping areas in Kelowna:

Orchard Park Mall, located along Harvey Avenue/Highway 97 and Cooper Road (10:00am - 6:00pm, except Wednesdays to Fridays until 9:00pm). Use bus routes 97 or 8.
www.orchardparkshopping.com

Downtown Kelowna stores typically open at 11:00am and close at 6:00pm. Use bus route 97.
www.downtownkelowna.com

Taxes

5% Good and Services Tax on all products and services
7% Provincial Sales Tax on most products and services
2% city levy is charged for motels, hotels, and resort accommodation.

Tipping

A tip is standard practice while dining out in Canada, however it is dependent on the quality of service you receive. Typically, adding 15% on your restaurant bill prior to taxes is common for tipping.

Smoking and Alcohol

The legal drinking age in Canada is 19, and bars and liquor stores require two pieces of identification to confirm your age. Smoking is not allowed inside any building; across campus there are various designated gazebos (small, covered wooden structures) to smoke cigarettes or cigars in.

Tourism Kelowna **www.tourismkelowna.com**

Inside your welcome pack there is a guide to Kelowna's tourism opportunities, including festivals and events, attractions and activities, entertainment and art, and day trips.

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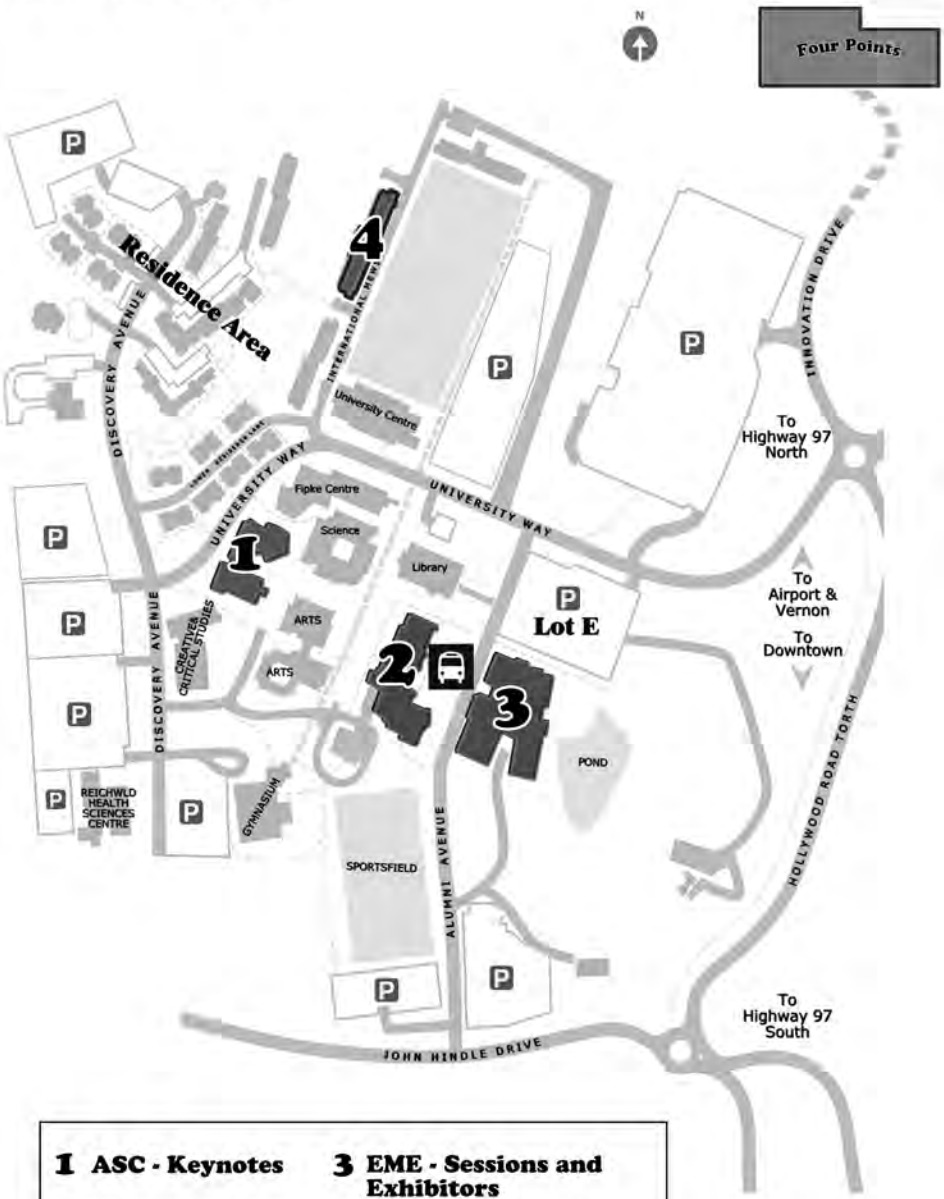
CAMPUS MAP



1 ASC - Keynotes	**3 EME - Sessions and Exhibitors**
2 ADM - Meals	**4 Accommodation Office**
Transit Exchange	**P Pay Parking**

Detailed schedules for the technical sessions are listed in chronological order starting on the next page. This is followed by a list of posters grouped by theme.

Abstracts for the keynote presentations and the remaining abstracts can be found after the schedules. Each abstract is assigned a unique number, and ordered by the last name of the first author. For each technical presentation, the abstract number is provided in square brackets [ ] within the schedule.

A cross-referenced index of all authors can be found after the abstracts.

Schedule in Detail

05-July		
14:00-20:00	Registration（EME upper mezzanine）	
18:00-20:00	ADM Sunshine Cafeteria open for dinner (Not covered by conference)	
06-July		
07:00-09:00	Breakfast (ADM Sunshine Cafeteria)	
07:00-10:00	Registration / Poster Setup（EME upper mezzanine and lower foyer）	
Opening Ceremony (ASC 140) MC: Nelson Jatel		
10:00-10:40	Welcoming Remarks	
10:40-11:00	Group Photo	
Keynote Talks I (ASC 140) Chaired by: Adam Wei		
11:00-11:30	Jeffrey McDonnell	Forests and water: New insights from stable isotope tracing [K-5]
11:30-12:00	Daniel Neary	Fire disturbance and hydrological processes in forested catchments at different spatial scales [K-6]
12:00-13:00	Lunch (ADM Sunshine Cafeteria)	
Keynote Talks II (ASC 140) Chaired by: Rita Winkler		
13:00-13:30	Richard Harper	Managing interactions between forests, ground and surface-water in a region affected by land-use and climate change [K-2]
13:30-14:00	Guoyi Zhou	Global pattern for the effect of climate and land cover on water yield [K-9]
14:00-14:30	Julia Jones	Forests and water in headwater catchments in the US and Canada [K-3]
14:30-15:00	Coffee break (ASC foyer)	
Keynote Talks III (ASC 140) Chaired by: David Scott		
15:00-15:30	Shirong Liu	An overview of forest hydrology research at multiple scales and biogeoclimatic zones in China [K-4]
15:30-16:00	Jim Vose	Revisiting forest management and water yield relationships in the Anthropocene [K-7]
16:00-16:30	Lu Zhang	Coupling of the carbon and water cycles for estimating future water availability [K-8]
16:30-18:00	**Poster Session (EME lower foyer)**	
18:00-20:00	**Reception (EME lower foyer)**	
19:00-20:00	**Young Scientists Salon (EME upper mezzanine)** (Organized by Dr. Jessie Tu and Christine Mettler)	

07-July Morning						
07:00-08:00	Breakfast (ADM Sunshine Cafeteria) / Registration (EME upper mezzanine)					
Time	**Session A1: Disturbance and hydrology: Water quantity** **Chaired by:** Dave Spittlehouse **(EME 0050)**		**Session B1: Climate, forest changes and hydrologic responses**: **Forest stand scale** **Chaired by:** Sampurno Bruijnzeel **(EME 1121)**		**Session C1: Applications of new methods and technologies (I)** **Chaired by:** Axel Anderson **(EME 1151)**	
8:30	Rita Winkler	A1-1:Clearcut logging effects on water yield at Upper Penticton Creek [143]	Kyoichi Otsuki	B1-1:Effects of thinning on the under-canopy microclimate in a Japanese cedar plantation, Japan [98]	Robin Pike	C1-1:Development and testing of a modified transparent head-velocity rod (mTHVR) for discharge measurement [99]
8:50	Pengtao Yu	A1-2:Runoff change in Jinhe River basin and its causes during last 50 years [148]	Antonio del Campo	B1-2:Addressing the eco-hydrological side of adaptive silviculture: Effects on the water cycle components, tree growth, biogeochemical cycles and soil properties [15]	Xiang Li*	C1-2:Rainfall interception by canopy and leaf litter in northern China: A joint measurement [80]
9:10	Dennis Hallema	A1-3:Evaluation of complex relationships between large historic wildland fires and streamflow in watersheds across the conterminous U.S. [51]	Kenji Tsuruta	B1-3:Interannual variations of and factors controlling evapotranspiration in a temperate Japanese cypress forest [130]	Bill Floyd	C1-3:Stream discharge measurements using an automated salt dilution system in a hyper-maritime watershed on British Columbia's central coast [39]
9:30	Gesa Meyer*	A1-4:Evapotranspiration and water use efficiency over eight years following mountain pine beetle attack in lodgepole pine stands in northern British Columbia [92]	Yuelin Li	B1-4:Atmospheric nutrient input and how it is influenced by forest succession stage in south China [81]	Gabe Sentlinger	C1-4:Derivation, uncertainty, and variance of the calibration factor used in salt dilution flow measurements [115]
9:50	Takashi Gomi	A1-5:How did runoff and stream temperature responses after 50% thinning differ among nested observations of headwaters? [46]	Malek Haghshenas *	B1-5:Climate effect on tree-ring widths of *Fagus orientalis* in the Caspian Forests of northern Iran [49]	Mohammad Pirestani	C1-5:Bankful-discharge estimation and determining of regime relation for mountain river (Case study: Ab Nik River) [101]
10:10	Coffee break (EME upper mezzanine and lower foyer)					

* Student presentation

07-July Morning						
Time	**Session A2: Disturbance and hydrology: Methods** **Chaired by:** Devendra Amatya **(EME 0050)**		**Session B2: Climate, forest changes and hydrologic responses**: **Small watersheds** **Chaired by:** Bill Grainger **(EME 1121)**		**Session C2: Applications of new methods and technologies (II)** **Chaired by:** Qiang Li **(EME 1151)**	
10:40	Peter Tschaplinski	A2-1:Carnation Creek watershed experiment – Long-term responses of coho salmon populations to historic forest practices [129]	Yuichi Onda	B2-1:Increasing in watershed runoff by the management practice of devastated forest plantation in Japan [160]	Ian Giesbrecht	C2-1:Introducing a new coastal margin observatory in the Pacific coastal temperate rainforest [43]
11:00	Johnny Boggs	A2-2:Paired forested watershed experiments in the piedmont of North Carolina [12]	Gebhard Schüler	B2-2:The impacts of a changing climate on water supply and flood mitigation in forested headwater catchments [112]	Michael Wagner	C2-2:The digital landscape of watershed analysis at large spatial scales [161]
11:20	John Diiwu	A2-3:Decision framework for post-wildfire salvage logging to protect watershed values in Alberta [27]	Shyue-Cherng Liaw	B2-3:Land cover change trajectories within eastern Taiwan of frequent natural disturbances [147]	U.E. Ekwugha	C2-3:Impact of agroforest technologies in watershed management in Imo State, southeastern Nigeria [34]
11:40	Catalina Segura	A2-4:Investigation of the scaling properties of the rainfall runoff generation processes and its relation to nutrient flushing mechanisms in the Oregon Cascade Mountains: A nested approach [114]	Arthur Vrechi	B2-4:Evaluating hydrological behavior of a paired catchment study in south of Brazil [133]	Paul Bartlett	C2-4:Changes to the parameterization of canopy albedo in response to snow interception and unloading improve the simulated albedo in the Canadian Land Surface Scheme [9]
12:00	Lunch (ADM Sunshine Cafeteria)					

* Student presentation

07-July Afternoon						
Time	**Session A3:Disturbance and hydrology: Water quality** **Chaired by:** Mark Johnson **(EME 0050)**		**Session B3: Climate, forest changes and hydrologic responses: Large watersheds or regions** **Chaired by:** Yanhui Wang **(EME 1121)**		**Session C3: Applications of hydrological models** **Chaired by:** Shyue-Cherng Liaw **(EME 1151)**	
13:30	Kevin Bladon	A3-1:In-stream phosphorus and nitrogen response to logging in high elevation, forested catchments [11]	Yipeng Yu	B3-1:Responses of streamflow to anthropogenic impacts in catchments with different landform features on the Loess Plateau, China [152]	Junyu Qi*	C3-1:Modifying the soil temperature module in SWAT for application in Atlantic Canada: Module development, validation and impacts on watershed modelling [102]
13:50	Sarah Mager	A3-2:Dissolved organic and inorganic carbon flux from forested mountain watersheds in southern New Zealand [90]	Chelcy Miniat	B3-2:Southern Appalachian forest tree growth response to hydroclimate variability [36]	Devendra Amatya	C3-2:Assessing hydrologic impacts of climate change on a low-gradient forested watershed using SWAT model [2]
14:10	David Maloney	A3-3:Evaluating forest road impacts on water quality in British Columbia [17]	Ping Zhou	B3-3:Effect of forest changes on runoff and sediment in Dongjiang watershed [155]	Sangjun Im	C3-3:Parameterization of SCS curve number on small forested watersheds from rainfall-runoff data [58]
14:30	Juan Blanco	A3-4:Site fertility is more important than climate to produce overyielding in mixed Scots pine - European beech stands [3]	Mingfang Zhang	B3-4:The hydrological responses to cumulative forest disturbances in six large watersheds, B.C. Interior, Canada [153]	Ryan MacDonald	C3-4:Application of process-based modelling to assess peak and low flow response to timber harvest scenarios in a mountain watershed [88]
14:50	Ashlee Jollymore*	A3-5:High tech meets low tech: Facilitating citizen science approaches through improvements in water quality analysis [62]	Richard Benyon	B3-5:Predicting mean annual streamflow using commonly collected inventory data in forested catchments [10]	Yue Qin	C3-5:Development of a distributed eco-hydrological model in the upper Heihe River [145]
15:10	Coffee break (EME upper mezzanine and lower foyer)					

* Student presentation

07-July Afternoon						
Time	**Session A4: Disturbance and hydrology: Water quality and aquatic biology** **Chaired by:** Kevin Bladon **(EME 0050)**		**Session B4: Climate, forest changes and hydrologic responses: Continental scale** **Chaired by:** Jim Vose **(EME 1121)**		**Session C4: Forest carbon and water (I)** **Chaired by:** Lu Zhang **(EME 1151)**	
15:40	Brian Heise	A4-1:Effects of clearcut logging on aquatic invertebrates in headwater streams of Upper Penticton Creek, British Columbia [54]	Peter Caldwell	B4-1:Impacts of changing forest structure and species composition on long term streamflow across the conterminous US [14]	Kelly Sherman	C4-1:Forest carbon and hydrology modeling in a multiple-value management regime [116]
16:00	Keith Story*	A4-2:Persistence of *Cryptosporidium parvum* in cattle feces in forested environments [124]	Yongqiang Liu	B4-2:An ensemble analysis of forest fuel moisture responses to climate change in the continental U.S. [87]	Honglang Duan	C4-2:Drought responses of two gymnosperm species with contrasting stomatal regulation strategies under elevated [CO2] and temperature [29]
16:20	Masanori Katsuyama	A4-3:Hydrological control of perpetual effects of forest disturbance on streamwater chemistry in a forested catchment [68]	Ning Liu*	B4-3:Vegetation dynamics and rainfall sensitivity of the Australia continent [85]	Masayuki Itoh	C4-3:Methane flux characteristics in temperate forest watershed under Asian monsoon climate [59]
16:40	Changjun Gao	A4-4:River discharge regulates relationships between catchment landscape components and C:N:P ratios in streams of the Xitiao River watershed, China [40]	Xiuzhi Chen	B4-4:Patterns and trends of China's soil moisture in the past 30 years [22]	Jennifer Knoepp	C4-4:Variation in carbon and nitrogen inputs and pools along an elevation, precipitation and vegetation gradient in southern Appalachian forests [71]
Lake Cruise	Depart UBC-O 17:15 from parking lot E; pick-up at 21:00					
Vines and Wines	Depart UBC-O 17:15 from parking lot E					
18:00-20:00	ADM Sunshine Cafeteria open for dinner (Not covered by conference)					

* Student presentation

08-July Morning

Time	Session A5: Reforestation and hydrological processes (I) Chaired by: Kyoichi Otsuki (EME 0050)		Session B5: Watershed assessment and planning (I) Chaired by: Rob Scherer (EME 1121)		Session C5: Forest carbon and water (II) Chaired by: Kelly Sherman (EME 1151)	
07:00 - 08:00	Breakfast (ADM Sunshine Cafeteria) / Registration (EME upper mezzanine)					
8:30	Xuexiang Chang	A5-1:Qinghai spruce (*Picea crassifolia*) forest transpiration and canopy conductance in the upper Heihe River basin of arid northwestern China [19]	Doug Wahl	B5-1:Assessment of forest harvesting and protection of water in community watersheds in British Columbia [134]	Mark Johnson	C5-1:Carbon drainage fluxes provide ecohydrological insights across spatial scales in a coastal Pacific watershed [61]
8:50	Steven Brantley	A5-2:Variations in canopy and litter interception across a forest chronosequence in the southern Appalachian Mountains [13]	Zaid Jumean	B5-2:Generating a provincial assessment procedure for watershed evaluation [65]	Kevin Bishop	C5-2:Carbon balance in the forested boreal landscape: The significance of the aquatic conduit in a variable climate [157]
9:10	Jeff Kelly	A5-3:The impact of capping thickness on water use of juvenile aspen and white spruce trees: A study on a reclaimed site at the South Bison Hills reclamation area in northern Alberta [69]	Randy Spyksma	B5-3:Advancing watershed management in British Columbia's Cariboo region: Forest licensee implementation of a risk-based approach to support timber development planning [123]	Gyan Chhipi-Shrestha*	C5-3:Assessment of carbon stock of highland and lowland wetlands: A case study in eastern Nepal [24]
9:30	Mark Gush	A5-4:Water-use and growth of indigenous tree species in South Africa [48]	Bill Grainger	B5-4:Hydrologic risk assessment in beetle-attacked southern interior BC watersheds [47]	Hyun Seok Kim	C5-4:The effects of thinning intensities on transpiration and productivity of 50-year-old *Pinus koraiensis* stands [70]
9:50	Katherine Elliott	A5-5:Long-term changes in water use and streamflow following grass-to-forest conversion [35]	Doug Lewis	B5-5:The application of a strategic-level watershed assessment procedure towards managing the unintended consequences of cumulative hydrologic effects in the southern interior of BC [78]	Jehn-Yih Juang	C5-5:Investigating exchange of carbon and water at a subtropical wetland ecosystem close to a metropolitan area [64]
10:10	Coffee break (EME upper mezzanine and lower foyer)					

* Student presentation

08-July Morning							
Time	**Session A6: Reforestation and hydrological processes (II)** **Chaired by:** Alexander Onuchin **(EME 0050)**		**Session B6: Watershed assessment and planning (II)** **Chaired by:** Doug Lewis **(EME 1121)**		**Session C6: Surface water - groundwater interactions** **Chaired by:** Anna Sears **(EME 1151)**	
10:40	Koichiro Kuraji	A6-1:The role of the litter layer on the hydrological response of a forested catchment [73]	Sylvain Jutras	B6-1:How hazardous is the lack of forest road maintenance to fish habitat in Quebec's public forested lands? [66]	Sheng Du	C6-1:Soil water budget and evapotranspiration based on measurements along soil profiles in two typical forest stands in Loess Plateau [28]
11:00	Dave Spittlehouse	A6-2:Inter-annual variability in interception, evaporation and drainage from high elevation forest, clearcut and regenerating stands in the interior of BC [122]	Lars Reese-Hansen	B6-2:The Watershed Status Evaluation Protocol (WSE): An approach to evaluating risk and condition in BC's watersheds with fish values [105]	Sheena Spencer	C6-2:Groundwater-surface water interactions in a Rocky Mountain catchment in Alberta, Canada [120]
11:20	Silvio Ferraz	A6-3:Assessing potential benefits of natural forest cover increase to hydrological processes in agricultural landscapes at southeast Brazil [38]	Richard Thompson	B6-3:A stategic approach to fish passage in BC [126]	Wei-Li Liang	C6-3:Spatial and temporal variations in the surface and subsurface water in a natural forested headwater catchment [82]
11:40	Yanhui Wang	A6-4:Variation of evapotranspiration and water yield along forested slopes and the corresponding spatial scale effect in the semiarid Liupan Mountain of NW China [141]	Dawn Machin	B6-4:Okanagan Fish Water Management Tool (FWMT) [89]	Neil Goeller	C6-4:Impacts of historical channel modification and water extraction (ground and surface) on surface water resources in Cowichan River, British Columbia [45]
12:00	Lunch (ADM Sunshine Cafeteria)					

* Student presentation

08-July Afternoon

Time	Session A7: Reforestation and hydrological processes (III) Chaired by: Yuichi Onda (EME 0050)		Session B7: Watershed assessment and planning (III) Chaired by: Peter Tschaplinski (EME 1121)		Session C7: Watershed hydrology assessments Chaired by: Robin Pike (EME 1151)	
13:30	Huimin Lei	A7-1:Attribution of decreasing discharge in a typical watershed of the middle Yellow River using a distributed ecohydrological model [76]	Faye Hirshfield*	B7-1:An indicator approach to watershed assessments: Water use and shale gas development in a forested landscape within the Simonette watershed, Alberta [56]	Ge Sun	C7-1:A comparison of watershed evapotranspiration estimated by multiple methods across the United States [126]
13:50	Ilja van Meerveld	A7-2:Effects of reforestation of degraded land on hydrological flow pathways and streamflow in Leyte, the Philippines [132]	Renee Clark	B7-2:Duteau Creek watershed assessment response plan [7]	Alexander Onuchin	C7-2:Conceptual approach to hydrological role evaluation of boreal forest [97]
14:10	Xiaoping Zhang	A7-3:Responses of baseflow to the vegetation restoration in the catchment, Loess Plateau of China [154]	François Robinne*	B7-3:Provincial-scale assessment of fire risks to water resources in Alberta [108]	Wenfei Liu	C7-3:Effects of forest changes on streamflow in three large forested watersheds, southeastern China [86]
14:30	Huimin Wang	A7-4:How does thinning affect the carbon and water balance of a coniferous plantation in subtropical China? [136]	Keith Duhaime*	B7-4:Contrasts in drinking water source protection: BC, Canada's community watersheds and Salta, Argentina's protected watersheds [31]	Rui Yan	C7-4:Trends of runoff–sediment behavior in flood events under vegetation restoration in a catchment on the Loess Plateau, China [84]
14:50	Hyung Tae Choi	A7-5:The impact of the reforestation on the baseflow regime in small forest catchments [25]	Russell Smith	B7-5:A Test of selected hydrologic models for operational application in the southern interior of BC [119]	Shusen Wang	C7-5:Assessment of water budget closure for Canada's watersheds [138]
15:10	Coffee break (EME upper mezzanine and lower foyer)					
	Keynote IV (EME 0050) Chaired by: Adam Wei					
15:40-16:10	Sampurno Bruijnzeel		Tropical reforestation impacts on water yield: Adding soil degradation to the equation for more realism [K-1]			
16:10 -17:30	**Closing Ceremony (EME 0050)**		Closing Remarks: Rita Winkler and Adam Wei			
			Announcement: 5th IUFRO International Conference on Forests and Water in a Changing Environment			
19:00 - 21:00	**Banquet**		Departs UBC-O at 18:15 from parking lot E; MC: Nelson Jatel			

* Student presentation

*Student poster

Hydrological Processes in Forested Watersheds	
Abraham Springer	Closing the water balance in semi-arid forests with a precipitation-sourced chloride mass balance technique to measure groundwater recharge [1]
David Spittlehouse	Influence of rainfall event separation time on the analytical modelling of canopy interception loss from a mature lodgepole pine (*Pinus contorta var. latifolia*) forest [16]
Carla Cassiano*	Drought responses of Eucalyptus plantation: A case study of paired catchments in Brazil [18]
Bin Chen	Effects of foliage clumping on the estimation of evapotranspiration: A model test against flux data in North America [20]
Zuosinan Chen	Various influence of stand density on the response of Chinese pine transpiration to environment in North China [23]
Tomohiro Egusa	Inter-catchment groundwater transfer in small forest headwaters, Japan [33]
Silvio Ferraz	Environmental and management factors affecting flow reduction on forest plantation in Brazil [37]
Guangyao Gao	Transpiration and canopy conductance variations of shelterbelt in an arid inland river basin of northwest China [41]
Rodrigo Hakamada	Transpiration, canopy interception and stem flow according to different spacing and genotypes in a high productivity eucalypt plantation [50]
Marino Hiraoka	Responses of streamflow to forest thinning in mature coniferous plantation forests: One-year analysis of pre- and post-treatments [55]
Hughie Jones*	Evapotranspiration, surface conductance and water-use efficiency of two young hybrid-poplar plantations in Canada's aspen parkland [63]
Hiroaki Kato	Influence of intensive thinning on water and sediment discharge in Japanese coniferous forest plantations [67]
Frances O'Donnell	Snow water equivalence (SWE) and soil moisture response to restoration treatments in headwater ponderosa pine forests [96]
Mohammad Pirestani	Investigation of effective parameters on flood wave celerity in mountain rivers with irregular compound sections [100]
Todd Redding	Limitations on the use of chloride mass balance to estimate of long-term root zone drainage and groundwater recharge on the sub-humid Boreal Plains, north-central Alberta [103]

Hydrological Processes in Forested Watersheds (continued)	
Kimika Sano*	Estimating annual loss and annual evapotranspiration in forested headwater catchments: Analysis of the short-term water balance in pre- and post-thinning [111]
Bruce Scott-Shaw	Applications of sap-flux density measurements for monitoring tree water-use in South African catchments [113]
Yoshinori Shinohara	The rate of soil erosion in a moso-bamboo forest of western Japan: Comparison with a broadleaved forest and a coniferous forest [117]
Jianhua Si	Correlation between groundwater depth and the natural vegetation in the low reaches of Heihe River [118]
David Spittlehouse	20 years of rainfall interception in a young coastal Sitka spruce forest [121]
Xinchao Sun	Impact of strip thinning on forest floor evaporation in a Japanese cypress plantation [127]
Jie Tu	Back propagation neural network models of sap flow velocity for *Pinus elliottii* in degraded red soil area of Jiangxi province [131]
Taeko Wakahara	Observation of canopy interception loss, rainfall distribution and wind effect on rainfall observation in matured beech forest [135]
Pei Wang	Plant status controlling the water/energy flux and seasonal variation in isotope composition of evapotranspiration for a temperate grassland ecosystem [137]
Wei Wang	Morphological characteristics of solute transport in soils of re-vegetation highway slope by image analysis [139]
Long Wei	Partitioning evapotranspiration into evaporation and transpiration in natural shrub land and plantation [142]
Janping Wu	Study on water balance of *Eucalyptus* plantations in subtropical China [144]
Lei Yang	Comparison of soil moisture dynamics in two re-vegetation watersheds in semi-arid regions [146]
Jian-Guo Zhang	Rainfall partitioning and soil water dynamic under continuous rainfall events in two typical forests in the loess hilly region of China [151]
Mark Castonguay	Relating forest plantation growth to LiDAR-DEM determined variations in soil condition [158]
Monique Goguen	Soil moisture regime preferences of forest vegetation, mapped at high resolution [159]

Climate Change, Disturbance and Land Use Impacts	
Markandu Anputhas*	Food security or forest conservation: A “prisoner’s dilemma” situation for the residents of the Okanagan region, Canada [5]
Pei-Jen Chen	Establishing an ecotoxicological approach to assess hazardous impact of emerging micropollutants in watershed [21]
Liangliang Duan*	The effect of climate warming on hydrology in a large alpine forested watershed in northeastern China [30]
Ilja van Meerveld	Effects of land use on the partitioning of precipitation into evapotranspiration, surface runoff and soil water recharge in eastern Madagascar [42]
Clayton Gillies	Erosion and sediment control practices for resource roads and stream crossings: A practical operations guide [44]
Lu Hao	Hydrological responses to urbanization in the urban–rural interface in Nanjing, China [53]
Junhua Yan	Chemical changes in leachate from forest floor under different acid rain conditions for three subtropical succession forests [60]
Randy Kolka	Climate change effects on hydrologic processes in northern forests [72]
Ichrak Lakhdhar*	Optimization of nickel ion removal from aqueous solutions by chitosan-polyethylene oxide electrospun nanofibers [74]
Sangjun Im	Spatial and temporal analysis of rainfall variability over Korea [75]
Qiang Li	A global review on the effects of land cover and climate changes on water resources at large watersheds: Implications for management [79]
Frederico Miranda*	Identification of critical segments on forest roads by LS factor and flow accumulation topographic and hydrological indexes to identify critical segments on forest roads [93]
Yin Ren	Geographical modeling of spatial interaction between human activity and forest connectivity in an urban landscape of southeast China [106]
Carolina Rodrigues*	Effects on water quality from timber harvesting and growing of Eucalyptus plantation [110]
Xilin Wang	Ecological problem analysis in the southwest China based on big data environment [140]
Jiao-jun Zhu	Effects of forest types in headstream region of Hun-River on water quality of outlets from forested catchments, northeast China [156]

Forested Watershed Management	
Markandu Anputhas*	Evolving land and water use in a semiarid British Columbia watershed [4]
Siti Bakar	The future direction of hydrological studies in an isolated tropical forest in Klang Valley, Malaysia [6]
Keith Duhaime*	Agent based modelling to assess the potential for *C. parvum* as a hazard from cattle faeces in forested drinking water catchments [32]
Doug Lewis	Development of a strategic level GIS indicator-based watershed assessment procedure for assessing cumulative hydrologic effects [77]
Carla Cassiano	Natural forest scenarios and hydrological responses in an agricultural watershed in Brazil [94]
Todd Redding	The Compendium of Forest Hydrology and Geomorphology in BC [104]
François-Nicolas Robinne*	Managing wildfires for water security: a risk-based approach [107]
Carolina Rodrigues*	Fast growing Eucalyptus plantations and water: what we already know from Brazilian experiences [109]

Forest Carbon, Nitrogen and Nutrients	
Paul Bartlett	Soil respiration in a deciduous mixedwood forest: Response to wetting and drying cycles in observations and simulations [8]
Emily Diack*	Sources of dissolved carbon in forested and grassland mountain watersheds in the Southern Alps, New Zealand [26]
Longfei Hao*	Evaluating the effects of nitrogen deposition on forest soil carbon cycle in northeast region of China [52]
Jun'ichiro Ide	Spatial variations in concentration and nitrogen and oxygen stable isotopes of river nitrate in a hilly and mountainous area, western Japan [57]
Yingchun Liao	Fine root biomass of Chinese fir and their responses to environmental factors in subtropical China [83]
Wenyuan Zhang	The response of alpine meadow soil middle elements to human disturbance in Wugong Mountain [95]
Yong-zhong Su	Interaction of vegetative patches and soil properties in the valleys of Qilian Mountains [125]
Guo-Qing Li	Carbon and nitrogen in natural oak communities with different climate conditions in northwest China [149]

[K-1]

Tropical reforestation impacts on water yield: Adding soil degradation to the equation for more realism

L.A. (Sampurno) Bruijnzeel[1, 2], Jorge Luis Pena-Arancibia[3], Mark Mulligan[2]

[1]Critical Zone Hydrology Group, VU University, Amsterdam, The Netherlands
[2]Visiting Research Fellow at King's College London, London, UK
[3]CSIRO Land and Water, Canberra, Australia

Abstract:

The widely accepted scientific view, that most of the increase in annual water yield after (experimental) forest removal occurs in the form of enhanced baseflows, is increasingly contradicted by real-world observations where soil degradation comes into play. Disturbed flow regimes in the form of diminished dry season flows due to the gradual loss of the former high soil infiltration capacity have been demonstrated for catchments from a few hectares to tens of thousands of km^2 and across the tropical rainfall spectrum. Likewise, the generally accepted contention that high water use of fast-growing trees planted on grass/scrubland invariably leads to diminished baseflows does not take into account the possibility that the (negative) effect of tree planting on water use may be compensated by the (positive) effect on infiltration and retention (the so-called 'infiltration trade-off' hypothesis). Controlled experimental studies in which soil degradation is not included do not pick up the trade-off effect and merely reflect the (undisputed) higher water use of trees. This paper reviews increasing evidence that the enhanced infiltration afforded by a well-developed vegetation cover established on highly degraded soils can exceed the higher water use of the same, with demonstrably improved dry season flows as a result. Furthermore, results of a global modelling exercise of the trade-off between changes in rainfall infiltration and vegetation water use after reforesting all degraded tropical land are presented. The greatest positive impact on baseflows is expected to occur most likely in highly degraded areas receiving high rainfall, while vegetation recovery under semi-arid conditions is suggested to lead to a gradual decline in both total flows and baseflows despite demonstrated positive effects on rainfall infiltration in the form of reduced stormflows.

Sampurno Bruijnzeel *received the Busk Medal of the Royal Geographical Society (UK) in 2005, recognising more than 40 years of research contributing to our understanding of hydrological processes in the humid tropics. Dr. Bruijnzeel has authored or co-authored more than 220 scientific publications, focussing on rainfall and cloud water interception, transpiration, runoff generation, nutrient cycling and sediment transport, as well as impacts of deforestation and reforestation on water yield, soil erosion and sedimentation. Dr. Bruijnzeel is professor of Land Use and Hydrology at VU University Amsterdam, as well as a Visiting Senior Research Fellow at King's College London.*

[K-2]

Managing interactions between forests, ground and surface-water in a region affected by land-use and climate change

R.J. Harper[1], J.K. Ruprecht[1], K.R.J. Smettem[1,2] and R.H. Froend[3]

[1]Veterinary and Life Sciences, Murdoch University, Murdoch, Australia
[2]School of Civil, Environmental and Mining Engineering, University of Western Australia, Nedlands, Australia
[3]Centre for Ecosystem Management, Edith Cowan University, Joondalup, Australia

Abstract

There have been profound changes to water balances in south-western Australia due to a range of factors, including (1) extensive deforestation for agricultural development, (2) reduced annual rainfall, (3) increased abstraction of groundwater for urban and rural use, and (4) changes in interception due to forest management. Water balance changes due to deforestation have in some cases been associated with the mobilisation of salt stored deep in the regolith, and discharge of this salt into streams. This is a region of around 250,000 km^2, with 50,000 km^2 of natural (predominantly eucalypt) and plantation forests (*Eucalyptus* and *Pinus* spp.), and a Mediterranean climate with annual rainfall that varies between 1250 mm/yr at the coast to 300 mm/yr at the inland boundary.

There are several examples of water balance manipulation through forest management resulting in changes to groundwater discharge, surface water yields and water quality. Past policy and key forest management strategies have included regulation of deforestation and groundwater abstraction, and encouragement of widespread reforestation through both government and private investment. More recently, there has been a decoupling between forests and water supply with the implementation of large scale desalinization of sea-water to 'climate-proof' urban water supplies.

The option exists to both increase water yield and improve water quality through actions such as forest thinning or reforestation, depending on local circumstances. However, apart from a few instances, there has been an insufficient scale of activity to impact watershed water balances. The reasons are largely economic, in particular a failure to properly value the water benefits of any treatments. Additionally, forest management is a hotly contested public policy area and this may preclude some options. Future carbon markets may provide new sources of income for land managers and drive landscape level restoration, but achieving broad scale adoption will depend on prevailing policy settings and price.

Richard Harper *is Chair in Sustainable Water Management and leader of Agricultural Sciences at Murdoch University, as well as a visiting professor with the Chinese Academy of Forestry. A lead author of the 2014 IPCC Fifth Assessment Report chapter on mitigation using agriculture, Dr. Harper is actively researching the use of carbon mitigation to drive landscape scale change in soil, water and forest management.*

[K-3]

Forests and water in headwater catchments in the US and Canada

Julia A. Jones

Geography, Oregon State University, Corvallis, OR 97331, USA

Abstract

Much of the current literature in hydrology is focused on climate change, and many recent studies attribute streamflow trends to climate warming. However, other biotic and social processes also affect streamflow, and omitted factors may mislead interpretations about climate change effects on hydrology. According to the dominant hypotheses of climate change effects on streamflow, increased air temperature will increase evapotranspiration and reduce snowpack, affecting water availability. However, vegetation responses to past disturbances, vegetation responses to climate variability, and changes in human water use associated with water management infrastructure, human behavior, and population growth may also concurrently alter streamflow. Post-disturbance succession in conifer forest headwaters reduced late summer water yield over 1960-2010 in Oregon, mimicking the expected effect of climate warming. Succession and vegetation adaptations to drought appeared to mitigate climate change forcing of evapotranspiration at multiple forested headwater sites in the US and Canada. Changes in human water use, such as water withdrawals or reservoir management, may also mimic or overprint expected effects of climate. Within the Columbia River basin, headwater basins above dams showed consistent albeit small declining trends in late summer streamflow over the period 1950-2012. However, very few streams below dams showed matching trends. Climate change is likely to bring surprises in streamflow trends due to ecological responses and water management.

Julia Jones *focusses on collaborative analysis of long-term needs in hydrology, climate and ecology, and is interested in interdisciplinary collaborations linking ecology, engineering, mathematics and computer science. Her research examines forest cover change, climate change and variability, and landscape disturbances and their effects on streamflow, plant distributions and biogeochemistry. Dr. Jones is Professor of Geography in the College of Earth, Ocean and Atmospheric Sciences at Oregon State University.*

[K-4]

An overview of forest hydrology research at multiple scales and biogeoclimatic zones in China

Shirong Liu[1], Mingfang Zhang[2]

[1]Chinese Academy of Forestry, China
[2]University of Electronic Science and Technology of China

Abstract

Understanding the key hydrological processes and properties of various forest types is crucial for ecosystem protection, water resources management and human well-being in China, especially given that large-scale reforestation has been taken place since the late 1990s. The past 50 years has witnessed numerous experimental and modeling studies of forest hydrology in China. There is still a lack of comprehensive understanding of the impact of forests on hydrological processes across multiple spatial scales and across biogeoclimatic zones in China. This review examines progress in studying the hydrology of China's forested landscapes. The major objectives of this review are: 1) to provide a general understanding of forest-water relationships across multiple spatial scales and biogeoclimatic zones; and 2) to identify research gaps in forest hydrology in China. Our understanding is that experimental studies of hydrological processes have been mainly conducted at a forest stand level rather than at a watershed scale. Hydrological studies at the forest landscape level are limited, and consist mostly of modeling analyses with insufficient investigation of feedback mechanisms between forests, water and climate. In addition, traditional hydrological studies of forests only focus on interactions between surface water and forests, with groundwater rarely being examined. This review can provide valuable insights for the future direction of forest hydrology, and useful guidelines for forest management and water resources planning in China.

Shirong Liu *is chief research scientist in Forest Ecology and Hydrology at the Chinese Academy of Forestry, and has been a visiting scholar at the University of Edinburgh and North Carolina State University. Dr. Liu's current research focusses on ecosystem C, N and hydrological processes, and their responses to manipulated soil warming and experimental drought in temperate natural forests and in subtropical planted forests in China, long term vegetation changes (activity, phenology and water use efficiency) in response to climate change along the north–south transect of eastern China, large watershed studies on forest cover and climate change in subalpine regions, and multifunctional forest management for ecosystem services. Dr. Liu was a board member of IUFRO between 2010 and 2014.*

[K-5]

Forests and water: New insights from stable isotope tracing

Jeffrey J. McDonnell[1,2,3]

[1]Global Institute for Water Security, University of Saskatchewan, Saskatoon, Canada
[2]School of Geosciences, University of Aberdeen, Aberdeen, Scotland, UK
[3]Department of Forest Engineering, Resources and Management, Oregon State University, Corvallis, OR, USA

Abstract

Changes in water balance following deforestation and afforestation are quantitative descriptions of forest-stream interactions, but these numbers often convey a false precision owing to the complex, nonlinear system that is the forested catchment. In many ways, the science of forest hydrology is able to particularize but not generalize. Here I explore how stable isotopes are aiding our ability to generalize and classify behavior. I show how stable isotopes reveal information that is often different and complementary to water balance estimates and rainfall-runoff analysis. Such information is revealing new behavior at multiple scales in time and space, including ecohydrological separation of plant xylem water and mobile soil water, diverse streamwater transit time scaling patterns, and hidden streamflow during and between storm events. These isotope approaches suggest less precision but perhaps more accuracy in terms of a mechanistic assessment of the water balance. I provide examples from diverse forested catchments in Oregon, New Zealand, Chile, Scotland and South Carolina.

Jeffrey J. McDonnell *is Professor of Hydrology and Associate Director of the Global Institute for Water Security at the University of Saskatchewan (Canada), Distinguished Professor of Hydrology (adjunct) at Oregon State University (USA), 6th Century Chair of Hydrology at the University of Aberdeen (UK) and Honorary Professor of Hydrology at the Nanjing Hydraulic Research Institute (China). Dr. McDonnell received the Dalton Medal from the European Geophysical Union, the Birdsall-Dreiss Distinguished Lecturer Award from the Geological Society of America, the Gordon Warwick Award from the British Geomorphological Research Group and the Nystrom Award from the Association of American Geographers. He is currently President-Elect of the AGU Hydrology Section.*

[K-6]

Fire disturbance and hydrological processes in forested catchments at different spatial scales

Daniel G. Neary

USDA Forest Service, Rocky Mountain Research Station, Flagstaff, Arizona, U.S.A.

Abstract

Wildfires and prescribed fires produce widely variable disturbances to hydrological processes at different scales. Although both can include high severity fires that produce significant changes in hydrologic response, radical differences in fire area and severity scales between the two types of fires determines the magnitude of response. Wildfire affects interception, litter storage of water, snow accumulation and transpiration, but more critically it impacts infiltration, streamflow, baseflow, stormflow and snow accumulation. Hydrological impact is a function of area burned, fire severity, post-fire climate and terrain. Combustion of the O horizon, creation of water repellency in the mineral soil, and pore clogging with ash are principally responsible for alterations in storm runoff dynamics that produce dramatic hydrological effects. Thus, storms with precipitation return periods of 20 to 25 years are able to generate stormflows with return periods of 1,000 years or more. This paper examines the effects of wildland fire on the aforementioned hydrological processes as they relate to fire severity, climate, and terrain.

Daniel G. Neary *is a Watershed Science Team Leader and Research Soil Scientist for the USDA Forest Service at the Rocky Mountain Research Station. In his 40-year career he has worked in New Zealand, North Carolina, Florida, and Arizona. Dr. Neary is currently an Adjunct Professor at Northern Arizona University and the University of Arizona. He has published over 400 papers and books, including chapters in two IEA Bioenergy books, on the water impacts of forest bioenergy programs. He has co-authored two books on the ecosystem impacts of wildland fire. Dr. Neary is currently in New Zealand working at the SCION Forest Research Institute.*

[K-7]

Revisiting forest management and water yield relationships in the Anthropocene

James M. Vose

USDA Forest Service, Southern Research Station, Center for Integrated Forest Science (CIFS) at North Carolina State University in Raleigh, NC, U.S.A.

Abstract

Decades of watershed research have provided a depth of understanding on relationships between forests and water, and how these relationships change in response to climate variability, disturbance and forest management. This understanding has facilitated a strong predictive capacity and the development of best management practices to protect water resources with active management. Despite this understanding, the rapid pace of changes in climate, disturbance regimes, invasive species, human population growth and land use expected in the 21st Century is likely to create substantial challenges for watershed management that may require new approaches, models, and best management practices. In particular, projections of increasing aridity and growing water demands for human uses are likely to increase water scarcity in regions that have historically experienced abundant water supplies. The transition from abundance to scarcity has the potential to challenge long-held forest management practices that alter hydrologic processes. In this presentation, I will project changes in water supply and demand for watersheds in the eastern US, examine how current management practices effect hydrologic processes, and describe new "water smart" forest watershed management approaches that could be used to deal with water stress and supply shortages in the eastern US.

James M. Vose *has 25 years of experience at the Coweeta Hydrologic Laboratory studying watershed ecosystem responses to disturbances and forest management. Dr. Vose's research approach spans the continuum from leaves to landscapes, and includes determination of the roles of species and natural and anthropogenic disturbances in regulating watershed ecosystem processes. He has led numerous interdisciplinary studies investigating ecosystem responses to prescribed burning, evaluating the effectiveness of riparian zone restoration and buffer widths, and quantifying ecosystem responses to climate change, forest management activities, and insect outbreaks. He has received numerous national and regional awards for both his research and science delivery, and has authored over 200 scientific papers. Dr. Vose recently served as co-lead author on the USDA National Climate Assessment Forest Sector Report and is co-editor on two books on climate change and forests.*

[K-8]

Coupling of the carbon and water cycles for estimating future water availability

Lu Zhang[1], Lei Chang[1], Yingping Wang[2]

[1]CSIRO Land and Water Flagship, Canberra, Australia
[2]CSIRO Oceans and Atmosphere Flagship, Australia

Abstract

Future climate change will significantly affect the global water cycle, and changes in water availability are of major concern. Water resources planning and adaptation to climate change rely on predictions of the exchange of carbon and water between the land surface and the atmosphere. Although the linkages between these components are well established, future water availability is often predicted using hydrological models with limited representation of physiological processes, and which tend to focus on streamflow predictions. In contrast, land surface models used in global climate models generally have detailed representation of ecophysiological processes, but their hydrological representations are often inadequate and are not calibrated with streamflow measurements. These differences often result in inconsistencies in simulated carbon and water budgets. Catchment scale water availability is affected by changes in both climatic variables (precipitation and temperature) and biological variables (canopy conductance and leaf area index (LAI)). The strong regulation of ecosystem carbon and water fluxes by stomata is well understood at the leaf level. However, at regional scales the coupling is complex, and is dependent on nonlinear physiological response of vegetation to soil water stress and elevated CO_2 concentrations. In this study, the ecohydrological model WAVES (calibrated against observed LAI and canopy transpiration estimated from FACE) was used to evaluate the impact of climate change on future water availability for catchments with different vegetation covers. Results suggest that coupling of carbon and water cycles can constrain LAI and evapotranspiration estimation and reduce uncertainty in the prediction of future water availability.

Lu Zhang *is a Senior Principal Research Scientist and Team Leader at CSIRO Land and Water Flagship in Australia, as well as Honorary Professor at the China Agricultural University and Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences. Dr. Zhang has over 20 year' research experiences in catchment hydrology, vegetation-water relationships, salt and water balance modelling and ecohydrology. He has published widely in these areas, with over 150 co-authored peer reviewed publications. Dr Zhang u is known internationally for his research on quantifying vegetation impact on catchment scale water balance and he was awarded CSIRO Chairman's Medal in 2008 for his contribution to Murray-Darling Basin Sustainable Yields Project.*

[K-9]

Global pattern for the effect of climate and land cover on water yield

Guoyi Zhou[1], Xiaohua Wei[2], Xiuzhi Chen[1], Ping Zhou[3], Xiaodong Liu[1], Yin Xiao[1], Ge Sun[4], David F. Scott[2], Shuyidan Zhou[5], Liusheng Han[6], Yongxian Su[6]

[1]South China Botanical Garden, Chinese Academy of Sciences, Guangzhou, 510650, China
[2]Earth & Environmental Sciences and Physical Geography, University of British Columbia Okanagan, Kelowna, British Columbia, Canada
[3]Department of Forest Ecology, Guangdong Academy of Forestry, Guangzhou, 510520, China
[4]Eastern Forest Environment Threat Assessment Center, USDA Forest Service, Raleigh, NC, 27606, USA
[5]Beijing Institute of Technology Zhuhai Campus, Zhuhai, 519088, China
[6]Guangzhou Institute of Geography, Guangzhou, 510070, China

Abstract

Research results on the effects of land cover change on water resources vary greatly and the topic remains controversial. Here, we use published global data to examine the validity of Fuh's equation, which relates annual water yield (R) to a wetness index (precipitation/potential evapotranspiration; P/PET) and watershed characteristics (m). We identified two critical values at P/PET =1 and m =2. m plays a more important role than P/PET when m<2, and a lesser role when m>2. When P/PET<1, the relative water yield (R/P) is more responsive to changes in m than it is when P/PET>1, suggesting that land cover changes in non-humid regions (P/PET<1) or in watersheds of low water retention capacity (m<2) can result in larger hydrological responses. m significantly correlates to forested area, watershed slope and watershed area. This global pattern has far-reaching significance in studying and managing hydrological responses to land cover and climate changes.

Guoyi Zhou *is a professor of ecosystem ecology, global change ecology, forest ecology and forest hydrology at the South China Institute of Botany, Chinese Academy of Sciences, in Guangzhou, China. Dr. Zhou is also the director of the Dinghushan Forest Ecosystem Research Station. Dr. Zhou has published in many international journals, including Science, Nature Communications, Global Change Biology and Water Resources Research, with significant contributions in the areas of reforestation hydrology, forest carbon and sustainability.*

[1] Poster

Closing the water balance in semi-arid forests with a precipitation-sourced chloride mass balance technique to measure groundwater recharge

Vaden Aldridge[1], Abraham E. Springer[1], Sharon Masek Lopez[1]

[1]School of Earth Sciences and Environmental Sustainability, Northern Arizona University, Flagstaff, AZ, U.S.A.

Abstract:

Better predictions of the response of perched and regional groundwater aquifers and their associated groundwater dependent ecosystems to landscape scale forest restoration can result from better measurements of groundwater recharge. Aquifer management is becoming more challenging as climate change-related drought and the risk of severe forest wildfire alter hydrologic processes and functions. In the Ponderosa pine forests of northern Arizona, recent landscape-scale forest fires have prompted the initiation of forest restoration projects to help decrease the amount of available fuels for fires and return the forest to a more resilient condition. Because these are the first landscape-level forest restoration treatments, new research is needed to assess hydrological responses. Monitoring groundwater resources in the region is difficult, however, as there are limited borehole data in the deep, regional aquifer system (>400m) as well as little and ephemeral surface flow. Previous studies have demonstrated the chloride mass balance (CMB) technique to be well suited for observing groundwater recharge in arid locations having undergone land-surface change. Chloride is a conservative, non-volatile environmental tracer that can be used to estimate groundwater recharge under a mass balance approach. Precipitation, soil-water, surface water and soil-core samples were analyzed for major cations, anions (including chloride) and oxygen and deuterium isotopes in two separate watersheds. Chloride concentrations in precipitation, soil-water and surface water samples were used to deduce groundwater recharge while soil-core chloride concentrations were used to generate paleoclimatic groundwater recharge conditions. This pilot study confirmed the lack of summer recharge derived from the "monsoon season".

Key words: groundwater recharge; chloride mass balance; forest restoration; Ponderosa pine; semi-arid

[2]

Assessing hydrologic impacts of climate change on a low-gradient forested watershed using SWAT model

Devendra M. Amatya[1], Sudhanshu Panda[2], Ge Sun[3]

[1]USDA Forest Service, Cordesville, SC, U.S.A.
[2]University of North Georgia, Oakwood, GA, U.S.A.
[3]USDA Forest Service, Raleigh, NC, U.S.A.

Abstract:

In this presentation we used the ArcSWAT model to assess the hydrology and water balance of a low-gradient, coastal forested watershed. The Turkey Creek watershed (52 km^2) is located within the Francis Marion National Forest at the headwaters of the eastern branch of the Cooper River, draining to the Charleston harbor adjacent to a rapidly growing urban area in South Carolina, U.S.A. High-resolution LiDAR data was used to develop a DEM for delineating watershed boundary. Other GIS-based spatial databases used in model development were 1m resolution NAIP land cover data, SSURGO and the National Forest soils database, and a slope classification map. Precipitation and weather data from stations within the watershed were used as model input along with other default SWAT database primary model inputs. Model calibration and validation for the baseline watershed condition was conducted using 5 years (2005-10) of stream flow data. The model performance in this forested watershed were compared with the less data-intensive ecohydrologic model WaSSI. The validated SWAT model is being further applied to analyze the hydrologic effects of potential climate change using two contrasting scenarios of future climate from regional climate models for 2015 to 2050. Projected future precipitation and air temperature from the Canadian Climate Change model (CGC1, hot and dry) and the British HadGCM2 (wet and cool) for the watershed were extracted with a spatial resolution of 50x70 km^2 or half degree longitude and latitude. Simulation results of water yield and evapotranspiration for these scenarios are being analyzed for the hydrologic response to climate change. This information will be important for making management decisions on ecohydrologic assessments for low-gradient forested watersheds in the region, particularly at the time when the National Forest is revising its next 10 years management plan.

Key words: WaSSI; HadGCM2; CGC1; water yield; evapotranspiration

[3]

Site fertility is more important than climate to produce overyielding in mixed Scots pine - European beech stands

Ester González de Andrés[1], Juan A. Blanco[1], Brad Seely[1], J. Bosco Imbert[1], Yueh-Hsin Lo[1], Federico J. Castillo[1]

[1]Universidad Pública de Navarra, Pamplona, Spain

Abstract:

Scots pine and European beech are two of the most important forest species in Europe and Spain, especially in the Pyrenees. However, scarce information is available about growth trends in the region's mixed stands, and how they may be impacted by climate change. To address this information gap, field and literature data were combined in the FORECAST-Climate model to simulate growth and yield over 100 years in two contrasting sites in the Western Pyrenees: a highly productive Mediterranean forest (Aspurz, 625 m a.s.l.) and a low productivity alpine site showing more continental conditions (Garde, 1335 m a.s.l.). Keeping total stand density constant at 5000 trees ha^{-1}, a replacement series design was simulated with five different pine to beech mixing density ratios: 1:0, 2:1, 1:1, 1:2, and 0:1. Three climate change scenarios were used: historic (no change), moderate (B2) and severe (A2). For all climate scenarios at both sites, total stand biomass was largest with a 1:1 pine to beech density ratio, supporting the hypothesis that mixed stands are more productive as site resources are more completely used. However, the overyielding effect was much more important in Garde, the less fertile site. This increase was mostly achieved by pine, with very little effect on beech. Differences among climate scenarios were small, indicating that the contrasting response of pine to the presence of beech appears to be controlled by competition and facilitation processes, which are modulated by site fertility conditions rather than by moisture limitations. On low fertility sites, pine benefits from nutrient input from beech litter, which reduces growth limitations for pine. In contrast, on fertile sites the highly competitive nature of beech results in reduced pine growth. Our results also show the utility of ecosystem-level models to explore interspecific interactions at the stand level.

Key words: *Pinus sylvestrsi*; *Fagus sylvatica*; mixedwoods; Pyrenees; climate change

[4] Poster
Evolving land and water use in a semiarid British Columbia watershed

Markandu Anputhas[1], Johannus Janmaat[1], Craig Nichol[1], Adam Wei[1]

[1]I.K. Barber School of Arts and Sciences, The University of British Columbia, Canada

Abstract:

British Columbia is a mountainous Canadian province with a limited supply of high quality agricultural land. Climate change and urban development are putting significant pressures on land and water resources throughout the Okanagan Valley, located in the southern interior of the province. We use the CLUE-S (Conversion of Land Use and its Effects at Small regional extent) system to forecast land use change for the Deep Creek watershed, in the northern Okanagan Valley. Understanding what factors are contributing to land use change and where that change is likely to occur can help local and regional governments better manage these changes.

Calibration highlighted two important results. First, including a variable capturing spatial correlation of land use types significantly increases the explanatory power of the model. Second, simple distance measures, such as distance to road or depth to groundwater, did not capture the influence of infrastructure such as water delivery systems. Water is essential for most agricultural activity in the watershed. If it is unavailable through a shared delivery system, farmers will use other surface sources or groundwater. Thus, it is access to delivered water, not distance to delivered water, which is the critical land use driver.

Model forecasts show continuing pressure on forest and range land. All new agricultural land will be former forest land, and all of this is low elevation land. Therefore, already-scarce low elevation forested habitats will be lost. These new agricultural lands will also need water, and where delivered water is not available, groundwater use will increase with consequent impacts on connected surface water bodies. Much of the new residential development will also be on forested land, again largely at lower elevations. Actively protecting low elevation forested lands and expanding water infrastructure to accommodate new agricultural lands may help to reduce adverse environmental impacts.

Key words: CLUE-S; Deep Creek watershed; land use change; simulation; water district

[5] Poster

Food security or forest conservation: A "prisoner's dilemma" situation for the residents of the Okanagan region, Canada

Markandu Anputhas[1], Johannus Janmaat[1], Craig Nichol[1], Adam Wei[1]

[1]I.K. Barber School of Arts and Sciences, The University of British Columbia, Kelowna, Canada

Abstract:

Land use types generally perform multi-functions in addition to their primary service. Usually, these multi-functions produce goods and services that are non-marketable and public in nature. Forest and range land also provides many valuable services to the environment. However, converting forest and range land to other land use purposes reduces the extent of the forest and range area and diminishes goods and services that are useful for humans and the environment. In this study, we project future land use change under four scenarios with the intention of minimizing forest and range land lost and evaluating the most viable land use change policy option. The CLUE-S (Conversion of Land Use and its Effects at Small regional extent) system is used to forecast land use change for the Deep Creek watershed in the northern Okanagan Valley, British Columbia, Canada. The projection suggests that development pressure absorbs productive agricultural land, causing food security issues in this region which is predominantly mountainous and non-arable; at the same time, reducing forest and range land leads to environmental vulnerability and increased carbon emission. As a consequence, a balance between agricultural and environmental priorities should be met to adjust for future land use conversion pressure.

Key words: CLUE-S; land use scenarios; multi functions; non-marketable goods and services

[6] Poster

The future direction of hydrological studies in an isolated tropical forest in Klang Valley, Malaysia

Siti Nurhidayu Abu Bakar[1], Mohamad Roslan Mohamad Kassim[1], Debbie Injan Anak Andrew Jumat[1], Mohamad Aizat Arippin[2], Mohamad Faizalhakim Ahmad Safuan[1]

[1]Department of Forest Management, Faculty of Forestry, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
[2]Planning and Assessment of Forest Resources Section, Forest Department of Peninsular Malaysia, Jalan Sultan Salahuddin, Kuala Lumpur, Malaysia

Abstract:

Forest patches or isolated forests within developed cities are considered "green lungs" that regulate the weather of surroundings area and function as water catchments. Isolated forests are threatened by the expansion of urbanization, which may affect hydrological processes and contribute to pollution of the water system. Ayer Hitam Forest Reserve (AHFR) is the only lowland dipterocarp forest in the rapidly developing Klang Valley, Peninsular Malaysia. The forest was 6267 ha in 1965, but shrunk to 1176 ha in 2015 (81.2% loss) due to forest operations between 1930 and 1983. Commercialization of the surrounding areas took place since then and is still on-going. The forest was left to regenerate naturally and was gazetted for education, research and expansion purposes. Since 1985, numerous hydrological studies have been conducted in the area, but they were poorly integrated. Challenges include the small hydrological system to work with and that adjacent urban areas influence hydrological processes. In addition, comparison with older studies is impossible due to shrinkage of forested area through conversion to urban area. Several hydrological studies have been conducted during 30 years post-logging were conducted in AHFR. Much lower suspended sediment concentrations (SSC) were recorded (0.17-6.2 mg/L) in the Upper Rasau River catchment, compared to a 1985 study from a disturbed catchment (2-1305 mg/L) and less disturbed catchment (1-292 mg/L). Water quality observations demonstrated that despite the high quality of stream water, during the dry period low pH (<5) values were recorded along the Rasau River. On the other hand, unclear rainfall-runoff relationships were also observed. Therefore, water source separation and soil-water interaction studies are needed in the future to understand discharge generation and storage capacity in the isolated forest.

Key words:

[7]

Duteau Creek watershed assessment response plan

John Bartell[1], Renee Clark[1]

[1]Regional District of North Okanagan, Canada

Abstract:

Duteau Creek is a drinking water source operated by Greater Vernon Water (GVW) for Vernon, Coldstream and outlying rural areas, British Columbia. Watersheds on Crown land in BC support multi-use activities such as forestry, range, mining and recreation (except in the Greater Vancouver and Capital Regional Districts). In 2008, many risks to drinking water were identified.

The Duteau Creek Watershed Assessment Response Plan (DCWARP) provides detailed and specific responses to each recommendation presented within the Duteau Creek Watershed Assessment (DCWA). As a condition on the operating permit, the DCWARP outlines the assessment recommendations, the work completed since the assessment, and a look at further actions to be completed by GVW, other users (stakeholders) and regulators responsible for water source protection.

It is important to note that GVW is not a regulator in water source protection. GVW does not have authority over land use practices on Crown land or land within municipal boundaries. GVW relies on Federal and Provincial acts, regulations, stewardship plans, best management practices and local government bylaws and policies to protect the water resource from the impacts of land use in the watershed.

Three main high risk activities that occur within the watershed include forestry, range (cattle) and recreation. These activities contribute to the majority of the risks and hazards that occur within the watershed. In an effort to minimize these and other associated risks identified in the DCWA, GVW has established a stakeholder technical advisory committee (TAC). The TAC group meets regularly to review progress in risk mitigation, and endeavours to identify roles and responsibilities within the watershed. This plan identifies how GVW and other TAC members have responded to the risks, hazards and recommendations identified in the 2008 DCWA report.

Although a considerable amount of progress has been made by GVW and other TAC stakeholders to address DCWA recommendations, there is still a significant level of effort needed to continue the work. This plan identifies specific action items that will be undertaken by GVW and other responsible organizations. The estimated time and cost to GVW is provided along with background information to provide insight on the rationale used for establishing response initiatives.

The DCWRP was accepted by the regional board of directors and Interior Health, and therefore implementation has proceeded.

Key words: drinking water; collaboration; integrated; multi-use; stakeholders

[8] Poster

Soil respiration in a deciduous mixedwood forest: Response to wetting and drying cycles in observations and simulations

Paul A. Bartlett[1], Ralf Staebler[2]

[1]Climate Processes Section, Environment Canada, Toronto, Canada
[2]Air Quality Processes Research Section, Environment Canada, Toronto, Canada

Abstract:

Measurements of soil respiration (*R*s) were made over six growing seasons at the Borden Forest, a 100 year old temperate deciduous mixedwood forest, located on the lands of the Canadian Forces Base Borden in southern Ontario. Measurements were made with a LI-COR model LI-8100 soil respiration system, using a 20 cm diameter automated chamber over a PVC soil collar and supplemented with occasional spatial measurements using a survey chamber on 30 additional soil collars.

The temperature sensitivity of *R*s, based on the Q_{10} value for volumetric soil moisture greater than 0.15, was 4.1 using half-hourly data and 4.5 using daily data. These are in the range of values reported for temperate and northern forests. Wetting and drying cycles are shown to have a strong influence on *R*s which decreases by more than 50% as soil moisture declines, but recovers quickly following rainfall and soil water recharge.

Differences between *R*s measured by the fixed chamber and spatial measurements are related to the soil moisture at each chamber location. Q_{10} values were essentially the same for the automated chamber and the spatial measurements, but soil collars located in areas of higher soil moisture showed slightly larger *R*s values. Measurements in three wells suggest that groundwater was not close enough to the surface to affect the near-surface soil moisture and respiration.

Simulations were conducted with the Canadian Land Surface Scheme (CLASS) coupled with the Canadian Terrestrial Ecosystem Model (CTEM). Patterns of *R*s were reproduced well during a dry year and during dry periods in general. During wetter periods, simulated *R*s was underestimated and the response to rainfall was muted. We believe this to be a result of underestimated soil moisture, combined with the parameterization of the sandy mineral soil without an explicit moisture-holding litter layer at the surface.

Key words:

[9]

Changes to the parameterization of canopy albedo in response to snow interception and unloading improve the simulated albedo in the Canadian Land Surface Scheme

Paul A. Bartlett[1], Diana L. Verseghy[1]

[1] Climate Processes Section, Environment Canada, Toronto, Canada

Abstract:

The Canadian Land Surface Scheme (CLASS) was modified to correct an underestimation of the winter albedo in evergreen needleleaf forests. Default values for the visible ($\alpha_{VIS,cs} = 0.17$) and near-infrared ($\alpha_{NIR,cs} = 0.23$) albedo of snow-covered canopy were too small, and the fraction of canopy covered with snow (f_{snow}) increased too slowly in response to interception. This produced a damped albedo response and an underestimation in winter. A new model for f_{snow} is based on z_{I*}, the effective depth of newly intercepted snow required to raise the canopy albedo to its maximum, which corresponds in the model to $f_{snow} = 1$. Snow unloading rates, extracted from visual assessments of photographs, were modeled based on relationships with weather variables, replacing the time-based method employed in CLASS.

New parameterizations were tested in CLASS 3.6 at boreal black spruce and jack pine forests in Saskatchewan, Canada, a subalpine Norway spruce and silver fir forest near Alptal, Switzerland, and a todo fir forest at Hitsujigaoka, Japan. The final model employs $\alpha_{VIS,cs} = 0.27$, $\alpha_{NIR,cs} = 0.38$ and $z_{I*} = 3$ cm. The baseline CLASS 3.6 produced an average (cross-site) index of agreement (d) (October – April) of 0.58. The best single-variable snow unloading algorithm was based on wind speed, and when combined with the new albedo and f_{snow} parameterizations, produced an average d of 0.86. Two unloading algorithms using ensemble averages of the unloading rate as a function of total incoming radiation and wind speed, and air temperature and wind speed, respectively, produced larger minimum but slightly smaller average d values of 0.84.

Allowing the fractional coverage of the canopy to increase more rapidly in response to snow interception, and the canopy albedo to reach larger snow-covered values, combined with weather-based unloading, has resulted in more realistic simulated winter albedo in evergreen needleleaf forests.

Key words:

[10]

Predicting mean annual streamflow using commonly collected inventory data in forested catchments

Richard Benyon[1], Patrick Lane[1], Dominik Jaskierniak[1], George Kuczera[2], Shane Haydon[3]

[1]The University of Melbourne, Australia
[2]The University of Newcastle, Australia
[3]Melbourne Water Corporation, Australia

Abstract:

This presentation examines whether a simple index of forest sapwood area, derived from measurements of stand density and mean tree circumference at 1.3 m height, provides useful insights into the relative effects of long-term spatial and temporal variation in climate and vegetation on mean annual streamflow. Mean sapwood thickness was measured in 15 *Eucalyptus regnans* and *E. delegatensis* stands, and a relationship derived to predict stand mean sapwood thickness from stand density (R-squared 0.72). Stand sapwood area, estimated as the product of predicted sapwood thickness and measured stand density and mean tree circumference, correlated strongly with observed stand sapwood area (R-squared 0.96). Forest inventory data from 14 forested research catchments, ranging in area from 4 to 122 ha, were used to estimate catchment sapwood area for undisturbed forests and at various times after some of the forests had been harvested and regenerated or thinned. Several decades of annual precipitation and streamflow measurements were also available from each catchment. There was a strong correlation (R-squared 0.88) between catchment sapwood area and catchment mean annual loss (annual precipitation minus annual streamflow averaged over periods of 1 to 4 years around the time of each forest inventory) and between catchment sapwood area and mean annual streamflow predicted as precipitation minus predicted loss (R-squared 0.89). In these catchments, change in vegetation cover, as indicated by changes in sapwood area, was the largest source of variation in mean annual streamflow, accounting for 70% more variation in mean annual streamflow than mean annual precipitation alone. Changes in catchment sapwood area accounted for 96% of the changes in catchment mean annual loss observed after forest thinning or harvesting and regeneration. We conclude that in even-aged forests, sapwood area estimated from commonly collected inventory data can be used reliably to predict spatial and temporal variation in catchment mean annual losses and streamflow in response to natural and imposed disturbances.

Key words: sapwood area; catchment loss; precipitation; streamflow; eucalyptus

[11]

In-stream phosphorus and nitrogen response to logging in high elevation, forested catchments

Kevin D. Bladon[1], Rita D. Winkler[2]

[1]Department of Forest Engineering, Resources, and Management, Oregon State University, Corvallis, OR, U.S.A.
[2]British Columbia Ministry of Forests, Lands and Natural Resource Operations, Kamloops, BC, Canada

Abstract:

The Upper Penticton Creek (UPCr) Watershed Experiment (49°39'N, 119°24'W) was established in 1984 with the broad objectives of quantifying changes in water quality and hydrologic processes related to forest harvesting and forest regrowth. Three study watersheds form the headwaters of Penticton Creek and drain approximately 26 km southwest to Okanagan Lake near the town of Penticton, British Columbia. The study design consists of one unlogged, control catchment (240 Creek) and two clearcut logged and reforested catchments (241 Creek and Upper Dennis Creek). The study catchments were harvested in a series of logging passes beginning in the fall of 1992 in 241 Creek and the fall of 1995 in Upper Dennis Creek – four years separated successive cuttings. Results will be presented on pre- and post-harvest concentrations and exports of phosphorus (P) and nitrogen (N), spanning the years 1992 to 2009. As limiting nutrients, P and N are a primary concern for aquatic ecosystem health, as elevated fluxes can result in considerable increases in primary productivity. Seasonal variability in P and N will also be compared and contrasted as related to variability in discharge and total suspended sediment.

Key words: limiting nutrients, forest harvesting, paired basins, water quality

[12]
Paired forested watershed experiments in the piedmont of North Carolina

Johnny Boggs[1], Ge Sun[1], Steven McNulty[1]

[1]USDA Forest Service, U.S.A.

Abstract:

Understanding how regional-specific water resources respond to disturbances can serve as useful information to land managers as they aim to set flow targets needed to maintain ecological integrity in surface waters or to design riparian buffers for water quality protection. Experimental forests in the Mountains and Coastal regions of North Carolina (NC) offer a long history of watershed hydrology and water quality data related to sustainability of forest and water resources following silvicultural activities. Little data is available for the Piedmont portion of the state. This study addressed this spatial knowledge gap using a series of paired watershed experiments. We found that discharge in treatment watersheds increased dramatically, ranging from 40% to 240% during the postharvest period (2011-2013). Total suspended sediment export in the treatment watersheds also increased significantly after harvest due to the increase of discharge quantity and movement of in-channel legacy sediment. Stormflow peak nitrate reached its maximum concentration during the first two years after harvest in treatment watersheds, then declined due to nitrate uptake by the rapid regrowth of woody and herbaceous plants. We found that 36% of the streambank trees were blown down in one treatment watershed due to opening of the canopy during harvest, but caused no measurable increase in mean daily stormflow sediment concentration. Residual trees in the buffer used 43% more water in the growing season postharvest (314mm) than preharvest (220mm). This resulted in an 8% change in stream discharge due to an increase in buffer stand transpiration. Our results align with forest management studies in the Mountains and Coastal plain where temporary increases in discharge were accompanied by increased in-channel sediment transport and nutrient exports, but were not sufficiently disruptive to impact aquatic life and ecological integrity. However, percent change in discharge and peak nitrate concentrations tended to be higher in NC Piedmont when compared to NC Mountain and Coastal plain regions.

Key words: paired watersheds; hydrology; water quality; blow down; best management practices (BMPs)

[13]

Variations in canopy and litter interception across a forest chronosequence in the southern Appalachian Mountains

Steven T. Brantley[1], Paul V. Bolstad[2], Stephanie Laseter[3], A. Christopher Oishi[3], Chelcy F. Miniat[3],

[1]Joseph W. Jones Ecological Research Center, Newton, Georgia, U.S.A.
[2]Department of Forest Resources, University of Minnesota, St. Paul, Minnesota, U.S.A.
[3]Coweeta Hydrologic Laboratory, USDA Forest Service Southern Research Station, Otto, North Carolina, U.S.A.

Abstract:

Variations in evapotranspiration (ET) have been documented across a variety of forest types and climates in recent decades; however, most of these data have focused on mature, second-growth stands. We present data on two important fluxes of water, canopy interception (Ic) and forest floor litter interception (Iff), across a chronosequence of forest age in the southern Appalachian Mountains. We used climate stations and throughfall collectors to measure gross rainfall and estimate Ic at each site, and a non-linear mixed model to determine the effects of forest age and precipitation on stand Ic. We also collected forest floor biomass monthly at each site and used these data in a model of litter wetting and drying to determine the quantity of water lost to Iff. Precipitation varied from 1679 to 2095 mm yr^{-1} across sites and across years (2011–2013). Canopy interception increased rapidly with forest age and then leveled off to a maximum of ~11% in an old-growth mixed-hardwood site. Despite differences in forest structure, forest floor biomass did not vary with age, suggesting either lower decomposition rates in younger sites, or likely high decomposition rates across all sites. Unlike Ic, modeled estimates of interannual variation in Iff were insensitive to annual rainfall amount and were dependent primarily on forest floor biomass. At all sites, Iff accounted for 4–6% of total precipitation and varied primarily due to differences in rainfall among sites with a higher percentage of Iff at sites with lower rainfall. Measurements are currently underway to validate the litter interception model using litter moisture probes and forest floor wet and dry weights. Improved estimates of interception will contribute to our understanding of how forest structure and climate variability affect forest water budgets and improve models of rainfall partitioning across the broader matrix of forest age classes.

Key words: evapotranspiration; interception; rainfall partitioning; forest regeneration; climate variability

[14]

Impacts of changing forest structure and species composition on long term streamflow across the conterminous US

Peter Caldwell[1], Kurt Smithgall[2], Chelcy Miniat[1], Ge Sun[3]

[1]Coweeta Hydrologic Laboratory, Center for Forest Watershed Research, Southern Research Station, USDA Forest Service, U.S.A.
[2]Pennsylvania State University, State College, PA, U.S.A.
[3]Eastern Forest Environmental Threat Assessment Center, Southern Research Station, USDA Forest Service, U.S.A.

Abstract:

In forested watersheds, climate change and changes in forest structure associated with stand age and species composition interact to affect watershed water yield (Q). In this study, we quantified changes in annual Q since 1961 at reference forested watersheds across the conterminous US, and separated the effect of changes in precipitation (P) and potential evapotranspiration (PET) from the effects of changes in forest structure. We compiled climate and streamflow data for 86 forested reference watersheds in the USGS Gages II database. We tested for breakpoints in Q, P, and evapotranspiration (ET) estimated as P-Q over time, and computed annual ET using a land cover-based Budyko model to estimate the impact of changes in P and PET on Q. Residual changes in Q after accounting for changes in P and PET were attributed to changes in forest structure and were verified using Forest Inventory and Analysis (FIA) data.

Preliminary results suggest that 23 of the 86 basins had significant ($p<0.10$) breakpoints in Q between 1961 and 2009. All sites in the northeast with significant breakpoints in Q had increases in Q and runoff ratio (Q/P) after the breakpoint, while results were mixed at sites in the eastern highlands and western mountains. Similarly, 22 of the 86 sites had significant breakpoints in ET, and 14 of these had higher ET after the breakpoint than before. Partitioning the changes in ET into changes in P and PET versus changes in forest structure revealed that P and PET have increased ET after the breakpoint at almost all 22 sites by up to 8.5%, while changes in forest structure have had mixed impacts on ET ranging from a reduction of 50% to an increase of 67%. These results suggest that changes in forest structure may have implications for the management of water supplies.

Key words: streamflow; water yield; evapotranspiration; forest structure; climate change

[15]

Addressing the eco-hydrological side of adaptive silviculture: Effects on the water cycle components, tree growth, biogeochemical cycles and soil properties

Antonio D. del Campo[1], María González-Sanchis[1], Antonio Lidón[1], Inmaculada Bautista[1], Cristina Lull[1], Guiomar Ruiz[2]

[1]Re-ForeST Universitat Politecnica de Valencia, Spain
[2] IAMA Universitat Politecnica de Valencia, Spain

Abstract:

In semiarid regions like the Mediterranean, natural water scarcity may be exacerbated both by climatic changes and high rain interception from unmanaged forests grown after land abandonment in upper watersheds. Proactive adaptive silviculture (e.g. reducing density) is recommended in these cases, although there is a need for an eco-hydrological background in order to fully understand the effects of these water-oriented treatments on water budgets, nutrient cycles and soil properties, within an ecosystem-based forest management approach.

The present study addresses the short-term eco-hydrological effects of a thinning treatment carried out in a Mediterranean marginal oak forest with the specific aims to i) increase forest growth and vigor, ii) modify the water cycle (decrease forest evapotranspiration and increase deep infiltration), iii) assess impacts on nutrient cycles and iv) assess changes in soil properties. The forest is located in a Mediterranean area in Valencia, eastern Spain. Two contiguous plots, control and treatment, were selected. The treatment plot was thinned in May 2012, reducing the density from 861 to 414 trees per ha. Throughfall, stemflow, runoff, soil moisture, deep infiltration, transpiration, tree growth and tree nutrient resorption proficiency were monitored for two years. N, P, K and C concentrations in rainfall throughfall, stemflow, runoff and soil leaching were also monitored.

Results indicate an early effect of thinning that optimizes the hydrological cycle, increasing throughfall, stemflow and soil moisture. Tree growth and transpiration increased and nutrient resorption proficiency decreased with the treatment. P and K in run-off water increased in the treated plot. On the contrary, soil respiration, water N and C contents were not significantly different between plots. From these results, we conclude that water-oriented forest management may optimize the hydrological cycle and enhance tree vigor without harming other elements of the forest ecosystem in the short term.

Key words: throughfall; transpiration; biogeochemical cycles; forest management; soil properties

[16] Poster

Influence of rainfall event separation time on the analytical modelling of canopy interception loss from a mature lodgepole pine (*Pinus contorta var. latifolia*) forest

Darryl Carlyle-Moses[1], David Spittlehouse[2]

[1]Department of Geography & Environmental Studies, Thompson Rivers University, Kamloops, British Columbia, Canada
[2]Competitiveness and Innovation Branch, Ministry of Forests, Lands and Natural Resource Operations, British Columbia, Canada

Abstract:

During the growing-seasons of 1998 and 1999, incident rainfall, throughfall and stemflow were measured in a mature lodgepole pine (*Pinus contorta var. latifolia Dougl.*) stand in the central interior of British Columbia as part of the Upper Penticton Creek Watershed Experiment. Respectively, interception loss, throughfall and stemflow accounted for 23.9 %, 75.9 % and 0.2 % of the 444.2 mm of cumulative incident rainfall over the two seasons. Two analytical models, the reformulated Gash model and the Liu model for use in sparse canopy forests, were evaluated for future use in this and similar stands in the region. In addition, the models were run using storm event separation time periods of 2, 6 and 12 hours. The reformulated Gash and Liu models underestimated observed interception loss by 17, 29, and 4 %, and 25, 35 and 13 % using storm event separation times of 2, 6, and 12 hours, respectively. Using derived canopy storage capacity and mean during-event evaporation rate data, the average time required for the canopy to dry was determined empirically to be ~ 12 to 15 hours. Good agreement between observed and simulated interception loss was found using a time separation period of 15 hours, with the reformulated Gash model simulating observed interception loss to within 1 %, while the reformulated Liu model underestimated interception loss by 7 %. The agreement between observed and simulated interception loss at the event scale for both models were also evaluated, and analyses were conducted to determine the sensitivity of the models to changes in parameter values.

Key words: interception loss; Gash model; Liu model; lodgepole pine; Upper Penticton Creek

[17]
Evaluating forest road impacts on water quality in British Columbia

Brian Carson[1], David Maloney[2]

[1]Consultant
[2]Ministry of Forests Lands and Natural Resource Operations, Canada

Abstract:

Industrial gravel roads are recognized as a leading cause of decline in surface water quality and change to flow regimes in British Columbia. Road networks increase the extent of disturbed forest floor as well as intercept water and direct it towards natural drainages. Over the last 8 years, the British Columbia Ministry of Forests, Lands and Natural Resource Operations under the Forest and Range Evaluation Program (FREP) has developed a field methodology to evaluate the impacts of roads on sediment generation. Sampling sites within a watershed are chosen based on the likelihood for road-induced artificial drainage into natural streams. Bridge and culverted crossings, roads parallel to and in close proximity to streams, and sites with excessive water interception are the focus for sample sites. Over 5000 sites have been assessed throughout the province, prioritizing the nature of impact that roads have on water quality. Government, industry and water purveyors have found the evaluation useful when prioritizing site mitigation.

The FREP methodology is being tested as a means of evaluating cumulative impacts of roads on watershed health. Depending on the size and density of a road network, a sampling transect is pre-determined to capture the range of representative sites. The sampled population includes newly constructed roads, established main lines, branch roads, lightly-used spur roads and deactivated roads, and their interaction with the natural stream network. The nature of the terrain through which the road is built, along with differing management levels associated with planning, design, construction and road maintenance, strongly influences a roads impact on erosion and sedimentation processes. Representative site assessments provide a basis upon which the whole watershed is evaluated. Within this framework, priorities for improvements to watershed management are presented.

Key words: watershed; evaluation; management; roads; sediment

[18] Poster
Drought responses of Eucalyptus plantation: A case study of paired catchments in Brazil

Carla Cristina Cassiano[1], Silvio Frosini de Barros Ferraz[2], Walter de Paula Lima[2], Carolina Bozetti Rodrigues[1], Arthur Vrechi[3], Rildo Moreira e Moreira[2]

[1] Forest Resources Graduate Program, University of São Paulo, Brazil
[2]University of São Paulo, Brazil
[3]Forestry Science and Research Institute

Abstract:

Fast growing forest plantations and water are components of a controversial topic worldwide. In addition, climate change is modifying precipitation amount in some regions, highlighting the importance of this theme. Available evidences shows that forest plantations cause reductions in stream flow, especially in early years of growth. It is hypothesized that the early years of a coppice rotation regrowth of Eucalyptus plantations have high potential to reduce stream flow due to the Eucalypts deep root system. We monitored stream flow at 15 minute intervals in three paired catchments over one hydrologic year (2013/2014) in southeast of Brazil, aiming to observe the impact of Eucalyptus coppice regrowth. The forest cover of catchments M1, M2 and M3 are 90%, 80% and 60%, respectively, of eucalyptus plantations, with the remaining proportions covered with native forest. Eucalyptus first rotation was harvested in the rainy season at catchments M2 and M3, while a mosaic of stand ages in catchment M1 was not harvested. An extreme dry condition was observed during the 2013/2014 hydrologic year, when annual rainfall was only 759 mm, as compared with the average mean of 1,500 mm. The ratio of evapotranspiration to precipitation was about 96% for the M2 and M3 catchments, while for M1 it was 80%. Water use by coppice was higher than the first rotation, when this relationship was 70%. Thus, the combination of coppice management associated with a drier year promoted a significant reduction in stream flow. However, the mosaic management in M1 showed that there are options to guide management activities, in order to reduce these impacts and avoid conflicts over water use. Other hydrological effects among paired catchments are discussed.

Key words: hydrology; stream flow; catchment; coppice; management

[19]

Qinghai spruce (*Picea crassifolia*) forest transpiration and canopy conductance in the upper Heihe River Basin of arid northwestern China

Xuexiang Chang[1], ZhiBin He[1], Wenzhi Zhao[1], Hu Liu[1], Xiao Wei[1], Bing Liu[1]

[1]Cold & Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, China

Abstract:

Tree transpiration plays a determining role in the water balance of forest stands and in water yields from forested catchments, especially in arid regions. In order to accurately estimate whole-tree water use and individual tree transpiration, it is important to have reliable information on radial patterns of sap velocity and responses of sap flow to local environmental conditions. Stand transpiration and canopy conductance were calculated for an 80 to 120 year old natural *Picea crassifolia* stand from measurements of sap flow and environmental variables during the 2011 and 2012 growing seasons. The experiment was carried out on Qilianshan Mountain, located in the upper Heihe River Basin in the arid region of northwest China. A simple Gaussian regression model for the radial distribution of sap flux velocity was calculated, which explained 92% of the radial profile variation of sap flow velocity. There was, however, no firm relationship between sap flow velocity and global shortwave radiation (R), vapour pressure deficit (D) or air temperature (T) because of the complex crown environment. Daily sap flow velocity on a clear day and soil moisture content were correlated, and described using a logistic regression. Total stand transpiration was 195.2 mm and 219.6 mm for the 2011 and 2012 growing seasons, respectively. Canopy conductance was sensitive to variations in climatic variables such as R, D, T and wind speed, and an exponential decay function using D and T accounted for 81% and 19% of the variations in canopy conductance, respectively.

Key words: sap flow; radial pattern; environmental factors; transpiration; canopy conductance

[20] Poster
Effects of foliage clumping on the estimation of evapotranspiration: A model test against flux data in North America

Bin Chen, Jing Chen, Jane Liu

1. International Institute for Earth System Science, Nanjing University, Nanjing, China
2. Department of Geography and Program in Planning, University of Toronto, Toronto, Canada

Abstract:

A process-based ecosystem model, the Boreal Ecosystem Productivity Simulator (BEPS), has been developed to simulate evapotranspiration (ET) at site, landscape, continental and global scales. BEPS simulates hourly ET using a two-leaf scaling method, that is, the canopy is separated into sunlit and shaded leaf groups and total ET is calculated as the sum of sunlit and shaded ET. Using this method, the BEPS model has been shown to be reliable in modeling the ET derived from eddy covariance (EC) measurements. In this study, we use the BEPS model to investigate the effect of canopy structure on the estimation of site-level ET. For this purpose, we use not only leaf area index (LAI) measured at the peak of growing season but also ground-based measurements of leaf clumping index. Characterizing the degree of deviation of the 3-dimensional leaf spatial distribution from the random case, the clumping index is used to separate the sunlit and shaded leaves for a given LAI. Our model results show that the site-averaged mean annual ET during the simulation period is 455 mm yr^{-1}. Relative to this baseline case, our results also show that (1) site-averaged mean annual ET is overestimated by 4% when accurate LAI is available but clumping is ignored, and (2) site-averaged mean annual ET is underestimated by 24% when the effective LAI is available and clumping is ignored. The clumping effects in both cases are statistically significant ($p < 0.001$). Effective LAI is often derived from remote sensing by inverting the measured canopy gap fraction to LAI without considering clumping. The simulated ET would therefore be underestimated when effective LAI is used. This is due to underestimation of the shaded LAI and therefore the contribution of shaded leaves to ET. We found that shaded leaves contribute to 52.8%, 57.9%, 66.9%, 60.6%, 69.1%, 72.8%, 77.1%, 68.0% and 65.1% to the total ET for the CA-SOA, US-Ha1, CA-SOBS, CA-SOJP, CA-EOBS, CA-TP39, CA-TP74, CA-HJP75 and US-Me2 sites, respectively. The average of this ratio is 65.6%.

Key words: clumping index; evapotranspiration; BEPS model; North America

[21] Poster
Establishing an ecotoxicological approach to assess hazardous impact of emerging micropollutants in watershed

Pei-Jen Chen[1], Sheng-Hsiang Ciou[1], Yao Chu[1]

[1]Department of Agricultural Chemistry, National Taiwan University, Taipei, Taiwan

Abstract:

Numerous synthetic chemicals have been introduced into aquatic ecosystems via human activities over the decades. However, very few anthropogenic chemicals are studied or monitored by regulators. Worldwide, emerging micropollutants (including pesticides, pharmaceuticals and personal care products) have been frequently detected in watersheds, including in surface water and groundwater supplies, and sewage effluent. Many compounds have been identified as endocrine disrupting compounds that can interfere with hormone function at minute concentrations, resulting in adverse effects on organism reproduction and development. Significant concerns about exposure risks and toxic impacts of emerging micropollutants on human health and environmental safety have been raised. However, there is presently no adequate integrated approach that assesses the hazardous effects of emerging micropollutants on the safety and sustainability of watersheds and aquatic ecosystems. Toxicity testing using *in vivo* mammal models (e.g. rodents) are often time- and labor-intensive and costly, underlining the need for an alternative animal model that is a rapid and cost-effective screening strategy for hazard prioritization of numerous pollutants. Medaka fish (*Oryzias latipes*) are a superior animal model used extensively in various fields because of its small size, short generation time, asynchronous spawning, ease of breeding, and relatively economic husbandry. This study aims to establish a systematic approach for toxicity assessment using a set of toxicity-based biomarker assays in medaka fish that reflect toxic responses, including molecular, enzymatic, physiological and behavioral changes, following chemical exposure. The established approach should fulfill the needs of scientific and regulatory communities for hazard prioritization and environmental risk assessment of emerging pollutants. The outcome could facilitate the management and regulation of watershed pollution and ensure ecological safety in the aquatic environment.

Key words: emerging micropollutants; toxicity assessment; environmental risk assessments; medaka fish

[22]

Patterns and trends of China's soil moisture in the past 30 years

Xiuzhi Chen[1], Guoyi Zhou[1], Wei Liu[2], Chongyang Wang[2], Jishan Liao[3]

[1]South China Botanical Garden, Chinese Academy of Sciences, Guangzhou 510650, China
[2]Guangzhou Institute of Geography, Guangzhou, 510070, China
[3]Department of Biological Sciences, University of Notre Dame, Notre Dame, Indiana 46556 U.S.A.

Abstract:

During the past 30 years, a significant decreasing trend in soil moisture ($p=0.044$) has been detected in Pacific Ocean exorheic drainage basins (PO-EXDB) of China, while soil moisture in Indian Ocean exorheic drainage basins (IO-EXDB) increased significantly ($p=0.001$) and varied slightly ($p=0.080$) in endorheic drainage basins (ENDB). Spatial analysis revealed that the cluster phenomenon of low standing soil moisture has spread to the whole ENDB region in 1980 and 1990, and is now occurring in the northeastern, central and southeastern PO-EXDB, which might lead to unexpected drought events in the future. Changing trends and variability in the ratio of precipitation to potential evapotranspiration (P/PET) are consistent with soil moisture in the PO-EXDB region, which suggests that a one percent decrease in P/PET might result in 0.84, 1.21 and 0.29 percent decreases in soil moisture in northern, central and southern PO-EXDB regions, respectively. Increases in regional river runoff is responsible for significant increases in soil moisture in IO-EXDB regions even though there is a decrease in P/PET, while the reduction of input river runoff is the major cause of decreasing soil moisture in ENDB regions despite increases in P/PET. In particular, large-scale afforestation is the probable reason for decreasing soil moisture in the Loess Plateau region. Overall, our results will be useful for mitigating the negative impacts of climate and land cover change on China's soil moisture.

Key words: soil moisture; climate change; forest change; runoff

[23] Poster

Various influence of stand density on the response of Chinese pine transpiration to environment in north China

Zuosinan Chen[1], Zhiqiang Zhang[1]

[1]Beijing Forestry University, Key Laboratory of Soil and Water Conservation and Desertification Combating, Ministry of Education, College of Soil and Water Conservation, Beijing, China

Abstract:

Understanding the response of transpiration to drought conditions is important for the conservation of forest ecosystems. The main objective of this study is to assess the factors (meteorological variables, soil moisture and stand density) which control transpiration in a Chinese pine plantation with different stand densities resulting from a variety of forest management measures. Half-hourly measurements of sap-flow were made over 2 years (2012-wet year and 2014-dry year) in three stands with various stand densities (2160 ha^{-1}, 1688 ha^{-1}, 983 ha^{-1}). Soil moisture was measured in each stand using TDR at two depths (20cm, 40cm), and a micrometeorology station was established around these stands. Results showed that, as stand density increased, there was a decrease in the proportion of rainfall that was used for transpiration (53%, 21% in 2012 and 32%, 16%, 16% in 2014). This decrease in transpiration could be caused by a decrease of sap-flow velocity with increased stand density, which may be explained by changes in soil moisture. Low soil moisture was measured in the 1688 ha^{-1} density stand, and sapwood density varied with stand density. Transpiration by Chinese pine in the low density stand is more sensitive to changes in solar radiation and vapor pressure deficit. Analysis of the relationship between sap-flow velocity and vapor pressure deficit under different weather conditions and soil moisture levels indicated that the observed decrease in transpiration with increased stand density was due to the sensitivity of sap-flow velocity to environmental factors. There was no clear relationship between sapwood density and Chinese pine stand density.

Key words: stand density; transpiration of Chinese pine; meteorological factors; soil moisture; sapwood density

[24]

Assessment of carbon stock of highland and lowland wetlands: A case study in eastern Nepal

Gyan Chhipi-Shrestha[1] Rejina Maskey[2], Bishok Dangol[2]

[1]University of British Columbia, Canada & Central Department of Environmental Science, Tribhuvan University, Nepal
[2]Central Department of Environmental Science, Tribhuvan University, Nepal

Abstract:

Wetlands deliver a wide range of critical services including carbon storage. The wetlands of Nepal are found from highland to lowland, but differences in carbon storage with locations remain unexplored. A study was carried out to determine the water quality, eutrophic status, and carbon stock of two wetlands: Timbung Pokhari (highland, 4330 masl) and Kechana Pokhari (lowland, 62 masl), both lying around 880 E longitude in eastern Nepal. Field sampling in the wetlands was conducted two times, in June 2012 (monsoon season) and November 2012 (post-monsoon season). Altogether, 30 sediment samples, 10 surface water samples, and 30 macrophyte samples were collected from each wetland in each season. Sediment Organic Carbon (SOC) in soil samples was determined using Walkey and Black's method, whereas water quality was assessed using APHA methods (1998). It was found that the Kechana Pokhari wetland was hypereutrophic, whereas the Timbung Pokhari wetland was mesoeutrophic. In particular, the total organic carbon of Kechana Pokhari water (34.48 ± 2.59 ppm) was significantly higher than that of Timbung Pokhari (8.43 ± 0.78 ppm). The hypereutrophic condition of Kechana Pokhari may be due to factors such as incoming nutrient-rich surface runoff, a warm climate, and optimum bottom strata for plant growth. Similarly, SOC was significantly higher in Kechana Pokhari (22.34 ± 1.08 kg m^{-3}) than in Timbung Pokhari (7.73± 0.37 kg m^{-3}), although sediment bulk density was significantly lower in Kechana Pokhari. The higher SOC measured in Kechana Pokhari may be primarily due to its geography, climate, and inflow of nutrients and fine sediments. In addition, the seasonal variation of SOC was significant in each wetland. This shows that lowland wetlands are rich in organic carbon content, and should be prioritized for conservation over highland wetlands.

Key words: wetland; total organic carbon; sediment organic carbon; water quality; eutrophic lake

[25]

The impact of the reforestation on the baseflow regime in small forest catchments

Hyung Tae Choi[1], Su-Jin Kim[1]

[1]Department of Forest Conservation, Korea Forest Research Institute, Seoul, Korea

Abstract:

Forests play a critical role as a source of clean water, covering 63% of the total area of South Korea. Many devastated areas in Korea have been reforestated since the 1970s. Now, the total reforested area reaches 2.2 million ha, and it is almost a third of the total forested land. Therefore, most of the forest lands in Korea have experienced big changes in hydrological regime.

The objective of this study is to evaluate the impacts of reforestation on the groundwater regime over time in a small forest catchment (13.6 ha) covered by coniferous forest plantations. The coniferous forests in the study catchment consist of *Pinus koraiensis*, *P. rigida* and *Abies holophylla* planted in 1976. Also, a neighboring small catchment (22.0 ha) covered by old natural deciduous forests was selected as a control. Rainfall-runoff monitoring has been conducted continuously since 1980 in the outlets of the both catchments.

Baseflow recession curve analysis and the hydrograph separation methods were used to detect changes in the groundwater regime in the catchments during last 30 years. A simple Linear Reservoir Model based on the exponential decay of streamflow was used to fit the recession curves empirically. Baseflow was separated for each year using the graphical hydrograph separation method and baseflow separation lines derived from recession curves.

In the planted coniferous forest catchment, 10-year average baseflow recession curve coefficients decreased from 0.025 in the 1980s to 0.018 in the 2000s, and the ratio of baseflow to total annual runoff increased from 60% in the 1980s to 73% in the 2000s. However, during the same periods, there were no remarkable changes to runoff in the natural deciduous forest catchment.

Long-term changes of the baseflow regime in the planted coniferous forest catchment show that low flow conditions improve after reforestation.

Key words: baseflow; reforestation; planted coniferous forest; recession curve; hydrograph separation

[26] Poster

Sources of dissolved carbon in forested and grassland mountain watersheds in the Southern Alps, New Zealand

Emily E. Diack[1], Sarah M. Mager[1], Robert Van Hale[2]

[1]Department of Geography, University of Otago, Dunedin, New Zealand
[2]Chemistry Department, University of Otago, Dunedin, New Zealand

Abstract:

Carbon cycling from plants and is an important component of terrestrial carbon fluxes. Carbon that is not recycled in the biosphere is exported to waterways in both particulate and dissolved forms. As carbon is moved between the atmosphere, biosphere and hydrosphere, it is fractionated so that different reservoirs develop distinctive isotopic signatures that can be used to determine the origin of the carbon. Dissolved inorganic carbon is derived from rock weathering and typically has a 13-C ratio of 0, whereas the oxidation and decay of organic carbon from plants typically has 13-C ratio approximating -24. Carbon routing through soils and groundwater may also have distinctive isotopic ratios that can be used to infer hydrological pathways through a watershed. The objective of this study is to use the stable isotopic composition of dissolved 13-C in mountain watersheds to determine the source of dissolved carbon in forested and grassland catchments in the Southern Alps of New Zealand. The stable isotopic composition of dissolved inorganic carbon (δ13C-DIC) across 60 study catchments varies over a large range (-16 to -3 ‰ (δ13C-DICvPDB)). Preliminary analysis shows watersheds that are forest-dominated have the most negative δ13C-DIC ratios, suggesting that the majority of dissolved inorganic carbon likely comes from the decay and oxidation of organic carbon within the watershed. By contrast, grassland-dominated watersheds have δ13C-DIC ratios similar to that of carbon derived from chemical weathering and dissolution of calcium carbonate, and that carbon cycling from the biosphere appears to be minor source in these waterways.

Key words: dissolved inorganic carbon; 13-C; Southern Alps; carbon flux; forested watersheds

[27]

Decision framework for post-wildfire salvage logging to protect watershed values in Alberta

J. Diiwu[1], M. Wagner[2], A. Anderson[3]

[1]Alberta Environment and Sustainable Resource Development, Edmonton, Alberta, Canada
[2]Alberta Environment and Sustainable Resource Development, Calgary, Alberta, Canada
[3]Foothills Research Institute, Hinton, Alberta, Canada

Abstract:

Forested watersheds are the source areas for a large proportion of the water supplying two-thirds of the population of Alberta. The majority of water supplies originate in the eastern slopes of the Rocky Mountains, headwaters to hundreds of communities in western Canada. Wildfires on these landscapes can have the potential for far-reaching and long lasting impacts on water supply, water quality and the aquatic environment at small and large watershed scales.

Wildfire is an integral part of a healthy landscape, yet it can have significant consequences on the hydrologic regime with widespread impacts on watershed values. In recent decades, many regions throughout the world have experienced earlier and longer fire seasons, with wildfires that are unprecedented in magnitude. This trend is forecasted to continue due to climate change. The shift in the wildfire regime, along with population growth and increased water demand, pose a significant challenge to downstream water utilities. Additional disturbances, such as salvage logging after a wildfire, has potential to have incremental impacts on watershed values. Considering economic opportunities that can be derived from fibre left behind after a wildfire, the decision to salvage log or not becomes a significant management challenge. Since fires are increasing in size, frequency and severity, the need for a framework for management decision-making regarding post-fire salvage logging continues to be great. A framework is therefore proposed to inform management decisions regarding post-wildfire salvage logging, with the goal of protecting watershed values. The proposed decision framework uses a matrix of burn severities along with watershed characteristics to determine a decision path for salvage logging versus no salvage logging.

Key words: wildfire; burn severity; watershed values; decision framework; salvage logging

[28] Poster

Soil water budget and evapotranspiration based on measurements along soil profiles in two typical forest stands in Loess Plateau

Sheng Du[1], Qiu-Yue He[1], Qiu-Wen Chen[1], Jian-Guo Zhang[1]

[1]State Key Laboratory of Soil Erosion and Dryland Farming on Loess Plateau,Northwest A&F University, Yangling, Shaanxi 712100, China

Abstract:

Quantified soil water budgets are needed for evaluation of the ecohydrological effects of vegetation types, particularly in dry lands. This work aims to comparatively investigate soil water dynamics and evapotranspiration in two major forest types.

Soil water content within 1 m depth were monitored by multiple sensors for two years in a natural oak forest and an adjacent black locust plantation. Stand conditions and meteorological variables were also measured. Instantaneous soil water storage was estimated from the weighted average of volumetric water contents according to the relative thickness represented by each sensor.

Soil moisture in the oak forest was slightly lower than in the black locust plantation throughout a year with normal precipitation, and became similar in a wet year. The plantation showed higher evapotranspiration and recharge, though it had a lower leaf area index. This suggests that the plantation's understory contributes considerable evapotranspiration, and that the oak forest's canopy intercepts considerable rainfall. Daily evapotranspiration in the oak forest was more stable than that in the plantation, especially during dry periods.

Results suggest that natural oak forests consume soil water more conservatively during dry period and may be more efficient in terms of water use. The black locust plantation transpires water vigorously in both dry and wet seasons, but has the advantage of water refilling due to its sparse structure.

Key words: evapotranspiration; Loess Plateau; semi-arid forest; soil water budget

[29]

Drought responses of two gymnosperm species with contrasting stomatal regulation strategies under elevated [CO_2] and temperature

Honglang Duan[1], Anthony P. O'Grady[3], Remko A. Duursma[2], Brendan Choat[2], Guomin Huang[2], Renee A. Smith[2], Yanan Jiang[1], David T. Tissue[2]

[1]Institute of Ecology & Environmental Science, Nanchang Institute of Technology, Nanchang, Jiangxi 330099, China
[2] University of Western Sydney, Hawkesbury Institute for the Environment, Hawkesbury Campus, Locked Bag 1797, Penrith, NSW 2751, Australia
[3] CSIRO Land and Water Flagship, Private Bag 12, Hobart, Tasmania 7001, Australia

Abstract:

Future climate regimes characterized by rising [CO_2], rising temperatures and associated droughts may differentially affect tree survival globally. As gymnosperms tend to have larger hydraulic safety margins, gymnosperms may be less vulnerable to hydraulic failure than angiosperms, and thus may be differentially impacted by future climate change. However, the interactive effects of elevated [CO_2] and temperature on plant responses to drought capable of inducing tree mortality remains generally unknown in gymnosperm species that differ in stomatal regulation. We examined water relations and carbon dynamics in two gymnosperm species with contrasting stomatal regulation strategies, *Pinus radiata* (relatively isohydric) and *Callitris rhomboidea* (relatively anisohydric), to assess response to drought as a function of [CO_2] and temperature. Both species were grown under two [CO_2] (400 ppm and 640 ppm) and two temperature (ambient and ambient + 4 °C) treatments in a sun-lit glasshouse under well-watered conditions. Plants were then exposed to an intense drought until mortality. Prior to mortality, leaf desiccation and extensive xylem cavitation occurred in both species, but significant depletion of non-structural carbohydrates was not observed in either species. Hydraulic failure was more likely to be the primary driver of mortality in both species, while carbohydrate depletion had minimal impacts. Elevated temperature resulted in faster mortality in *P. radiata*, but did not modify mortality rates in *C. rhomboidea*. Elevated [CO_2] did not ameliorate the negative impacts of drought and elevated temperature on either species. In summary, stomatal regulation strategies did not generally affect the relative contributions of hydraulic failure and carbohydrate depletion to mortality under severe drought. Elevated temperatures had a greater influence than elevated [CO_2] on drought responses in these two gymnosperms.

Key words: hydraulic failure; non-structural carbohydrates; rising [CO_2]; rising temperature; stomatal regulation

[30] Poster

The effect of climate warming on hydrology in a large alpine forested watershed in northeastern China

Liangliang Duan[1], Xiaohua Wei[2], Tijiu Cai[1], Xiuling Man[1], Qiang Li[2], Zhengxiang Yu[1]

[1]School of Forestry, Northeast Forestry University, Harbin 150040, China
[2]Earth and Environmental Sciences Department, University of British Columbia (Okanagan), Kelowna, BC V1V 1V7, Canada

Abstract

Permafrost degradation or thawing is an emerging ecological issue in alpine regions because of global warming. Several studies have indicated that permafrost thawing has significant effects on hydrological processes, and is a major concern for watershed management. In this paper, the impact of permafrost degradation over the past 40 years (1972-2012) on flow in the Duobukuer River watershed (3094 km^2), a large alpine forested watershed in northeastern China, was quantified. Annual streamflow and mean, maximum and minimum temperature increased significantly ($p<0.01$ for both Mann-Kendall tau and Spearman rho tests). Significant changes in annual streamflow and mean temperature were detected in 1988, so the study period was divided into reference (1972-1988) and warm (1989-2012) periods. No significant permafrost thawing occurred during the reference period, but modified double-mass curve (MDMC) and sensitivity-based analysis indicated that thawing during the warm period had a significant impact on streamflow. An empirical model was developed based on the relationship between changes in annual water yield and temperature. This model was used to project the effects of future permafrost degradation on streamflow, which will guide watershed management in the northeast of China.

Keywords: climate warming; permafrost degradation; streamflow increment; alpine forested watershed

[31]

Contrasts in drinking water source protection: BC, Canada's community watersheds and Salta, Argentina's protected watersheds

Keith Duhaime[1], M. Laura Gatto D'Andrea[2], Lucas Seghezzo[2], Martin A. Iribarnegaray[2], Soledad Rodriguez[2], John Janmaat[1], Deborah Roberts[1]

[1]University of British Columbia, Kelowna, Canada
[2]Universidad Nacional de Salta, Salta, Argentina

Abstract:

The province of British Columbia (BC), Canada has designated 466 watersheds with the status of Community Water Supply Watersheds ('Community Watershed'). Similarly, the province of Salta, Argentina has designated catchments with protective status and/or special management status for protecting surface drinking water sources. Forested watersheds are one of the primary sources of drinking water globally. In both instances, these catchments are defined as 'multi-use', since, in addition to providing drinking water, they also provide environmental, economic, and social benefits to communities. The need to mitigate hazards to drinking water quality and quantity must be balanced against the hazards posed by other activities and the benefits they provide. British Columbia has instituted an approach of developing best management practices to accomplish this objective. Salta's water purveyor, Aguas del Norte, in conjunction with the Universidad Nacional de Salta (UNSa) has developed a Water Safety Plan following principles set forth by the World Health Organization. The environmental, economic, and socio-political conditions and challenges to the protection of drinking water in each instance are unique. This paper will provide an overview, comparison, and contrast of these conditions and the governances, approaches, and methodologies used in each jurisdiction to assure sustainable drinking water quality and quantity. Of particular interest will be the creation and administration of a Water Safety Plan in the Las Costas Watershed serving Salta, and the creation and administration of best management practices for protecting drinking water in BC. The paper will explore these differences using a strengths, weaknesses, opportunities and threats (SWOT) analysis, providing insight into more effective and sustainable approaches to protect other drinking water catchments.

Key words: watershed; water safety plan; risk; best management practices

[32] Poster

Agent based modelling to assess the potential for *C. parvum* as a hazard from cattle faeces in forested drinking water catchments

Keith Duhaime[1], Deborah Roberts[1], M. Laura Gatto D'Andrea[2], Juan José Correa[2]

[1]University of British Columbia, Kelowna, Canada
[2]Universidad Nacional de Salta, Salta, Argentina

Abstract:

The province of British Columbia (BC), Canada, has designated 466 watersheds as Community Water Supply Watersheds (Community Watersheds). Similarly, the province of Salta, Argentina, has designated protection status for watersheds providing drinking water. *Cryptosporidiosis* outbreak incidents in the communities of Cranbrook and Kelowna, BC, in 1996 generated public concern about the presence of grazing cattle in community watersheds. An audit of forest practices in 2010 has led to the development of a pilot project in four community watersheds to develop best management practices (BMPs) to mitigate the potential for this hazard. Subsequently, there is pressure to expand the use of these BMPs in other watersheds. Aguas del Norte, the water purveyor for the province of Salta, is also considering BMPs to protect its water sources from the effects of cattle and other livestock. Effective and efficient deployment of these BMPs dictates that decision makers have an understanding of the expected behaviour of cattle in a watershed, including their routes of migration, and where, when, and how long they might access resources (feed, water, shade, and shelter). Of particular interest is the time spent by cattle within the riparian area along watercourses. One possible approach to quantifying and gaining insight to these challenges is to use modern agent based modeling techniques. This paper will explore the development, implementation and validation of an agent based model as a tool to address these challenges.

Key words: watershed; cattle; agent based modeling; risk; best management practices

[33] Poster
Inter-catchment groundwater transfer in small forest headwaters, Japan

Tomohiro Egusa[1], Takanori Sato[1], Tomoki Oda[1], Masakazu Suzuki[1], Yoshimi Uchiyama[2]

[1]University of Tokyo, Japan
[2]Kanagawa Prefectural Government, Japan

Abstract:

In forested headwaters, groundwater moves beyond the watershed boundary to infiltrate through bedrock or gaps between the surface and bedrock watershed boundary. These inter-catchment groundwater transfers are expected to significantly influence streamwater discharge and dissolved matter concentrations. However, to date, few studies have quantitatively measured inter-catchment groundwater transfer. In addition, most of the previous studies investigated groundwater transfer rates at annual intervals. Our objective was to determine groundwater transfer rates in small forested headwaters at higher-resolution timescales, and to clarify their determining factors.

Precipitation and streamwater discharge were monitored for 4 years in the Tanzawa catchment, Japan. The Tanzawa catchment is composed of two nested catchments (No.1 and No.4) and one neighboring catchment (No.3). Annual groundwater transfer was previously determined using chloride mass balance analysis. Catchment No.1 (48ha) had only small groundwater transfer. Groundwater infiltrated the bedrock and drained without passing through the weir gauge in catchment No. 3 (7ha), and groundwater flowed in from the neighboring catchment to catchment No.4 (5ha).

We applied a short-time period water-budget method, where the difference between the sum of precipitation and the sum of discharge in the interval between two given points in time can be regarded as the water loss. In catchment No.1, water losses were almost identical to the sum of transpiration and interception, which indicates that the water losses occurred as evapotranspiration. In catchments No.3 and No.4, groundwater transfer rates were calculated by subtracting the water losses in No.1 from those in No.3 and No.4. In catchment No.3, groundwater infiltration rates were almost constant throughout the year. In catchment No.4, groundwater inflow rates were strongly dependent on rainfall rates, which suggests that increases in groundwater levels determined groundwater inflow rates in this catchment.

Key words: groundwater transfer; water loss; evapotranspiration; bedrock; short-time period water-budget method

[34]

Impact of agroforest technologies in watershed management in Imo State, southeastern Nigeria

U.E. Ekwugha[1], M.C. Onyema

[1]Department of Forestry and Wildlife Technology, Federal University of Technology, Owerri, Imo State, Nigeria

Abstract:

The soils of the southeastern Nigeria, usually referred to as coastal plain sands, are classified as sandy ultisols. They are acidic, coarse textured, highly leached upland soils with low mineral reserves, having problems of soil erosion, poor water retention capacity and permeability, soil moisture deficiency, and low availability of nutrients (low fertility) which limits agricultural production and in turn gives rise to shortages of food supply. These and other natural and human-induced processes that operate on watersheds lead to degradation in this terrain of this region. Food security and environmental degradation are two main challenges facing humanity. Protecting and strengthening watershed ecosystems are the main strategies to address these issues. Establishing agroforests at watershed scales is important, as agroforest technologies are best suited to address issues of global hunger, poverty and environmental damage by improving watershed productivity, soil and stream conservation and protection, promotion of biodiversity, landscape enhancement and carbon sequestration, by maintaining and enhancing ecosystem services while increasing sustainable production and safeguarding nutritional quality. It provides a tool for accelerated improvement in rural economies in a country where over half of the population resides in the countryside. So far, only limited research has been undertaken in agroforest technologies and watershed management in the southeast ecological zone of Nigeria. This paper examines the impact of agroforest technologies in watershed management, emphasizing previous initiatives, success stories of community-based integrated projects, and the benefits of the techniques.

Key words: impact; agroforest; technologies; watershed management; environmental degradation

[35]

Long-term changes in water use and streamflow following grass-to-forest conversion

Katherine J. Elliott[1], Chelcy F.Miniat[1], Peter V.Caldwell[1], Steven T. Brantley[2], James M. Vose[3], WayneT.Swank[1]

[1]Coweeta Hydrologic Laboratory, Center for Forest Watershed Research, Southern Research Station, USDA Forest Service, U.S.A.
[2]JosephW. Jones Ecological Research Center, U.S.A.
[3]Center for Integrated Forest Science, Southern Research Station, USDA Forest Service, U.S.A.

Abstract:

Most southern Appalachian forests have been harvested since the 1880s. Many currently forested areas were previously cleared for agriculture or pasture, and then abandoned to revert back to forest (old-field succession). Watershed 6 (WS6), an experimental watershed in the Coweeta Basin, experienced a typical disturbance regime: clearcut and burned in 1958; fertilized and converted to grass (*Festuca octiflora*) for five years; herbicided to remove grass cover in 1966; and reverted to forest by natural regeneration. The original objective of this treatment was to test the effects of grass cover vs. deciduous forest on the quantity and timing of streamflow. Here, we quantified the long- term (1934–2013) changes in 1) aboveground biomass and species composition; 2) annual precipitation (P), evapotranspiration (ET) and water yield (Q); and 3) species- and functional (hydraulic architecture) group-specific estimates of transpiration for WS6 and an adjacent reference (WS14) watershed.

Aboveground biomass was comparable between WS6 and WS14 before the clearcut (222.93 vs. 234.45 Mg ha^{-1}), and again after 45 years of forest regeneration (201.47 vs. 243.81 Mg ha^{-1}). However, species composition had changed in WS6 from a forest dominated by species with ring-porous xylem that have conservative water use, to one dominated by diffuse-porous xylem species which have higher growing season water use. Q and ET (calculated as P-Q) in WS6 recovered to pretreatment levels by 1977, but after 1985 Q was less than and ET more than expected, a pattern that has continued through present day.

Key words: evapotranspiration; xylem anatomy; southern Appalachians; old-field succession

[36]
Southern Appalachian forest tree growth response to hydroclimate variability

Katherine J. Elliott[1], Chelcy F.Miniat[1], Neil Pederson[2], Stephanie H. Laseter[1]

[1]Coweeta Hydrologic Laboratory, Center for Forest Watershed Research, Southern Research Station, USDA Forest Service, USA
[2]Harvard Forest, Harvard University, USA

Abstract:

Climate change is predicted to become a major factor affecting tree species growth and distribution. Trees growing under the same climatic conditions may differ in their growth pattern according to site conditions. We evaluated the climate-driven patterns of growth for six dominant hardwood species in the southern Appalachians. We categorized species into two main functional groups based on stomatal regulation and xylem architecture: isohydric, diffuse-porous and anisohydric, ring-porous. We hypothesized that: (1) there will be species-specific differences in growth that will be conditional on topographically-mediated soil moisture availability; (2) in extreme drought and wet years, ring-porous species will have different growth responses than diffuse-porous species; and (3) multiple hydroclimate variables will have direct and indirect effects on growth for each functional group. Using standardized tree-ring chronologies, growth of diffuse-porous (*Acer*, *Liriodendron*, and *Betula*) and ring-porous (*Quercus*) species were examined *versus* on-site climatic data from 1935 to 2003. *Quercus* species growing on upslope sites had higher basal area increment (BAI) than their corresponding species growing in cove sites, whereas *Acer*, *Liriodendron* and *Betula* had lower BAI on upslope compared to cove sites. Across functional groups and topographic positions, growth was more sensitive to how precipitation was distributed (number of small storms and dry spell length) rather than to the total amount of precipitation. Structural equation modeling indicated that diffuse-porous species growing on dry sites were the most sensitive to climate ($r^2 = 0.46$), while ring-porous species growing on dry sites were the least sensitive ($r^2 = 0.32$). Spring precipitation, spring *D* and summer storms explained a large proportion of the variation in summer *AET/P*, and summer *AET/P*, growing season small storms and dry spell length partially explained radial growth. Decreasing the number of small storms and extending the number of days between rainfall events can result in significant growth reduction, even in regions with relatively high total annual rainfall.

Key words: tree-rings; small storms; xylem architecture; drought; structural equation modeling

[37] Poster
Environmental and management factors affecting flow reduction on forest plantation in Brazil

Silvio F. B. Ferraz[1], Walter de Paula Lima[1], Carolina Bozetti Rodrigues[2], Arthur Vrechi[3], Lara Gabrielle Garcia[2], Carla Cristina Cassiano[2]

[1]University of São Paulo, Brazil
[2]Forest Resources Graduate Program, University of São Paulo, Brazil
[3]Forestry Science and Research Institute, Brazil

Abstract:

The area of forest plantations in Brazil reached about 6 million hectares in 2014 due to internal and external demand for fiber and wood. Due to the high variability of climatic conditions, water use is a concern in some regions, especially considering climate change and the expansion of plantations to drier areas. In Brazil, previous observations show that a "plantation effect" can reduce flow by 10 to 30% depending on physical and management conditions. Based on long-term stream flow data from many experimental catchments in forest plantation areas, we show examples of environmental conditions at the regional scale, and local conditions and management options that could increase or attenuate the flow effects of forest plantations. Results show that it is important to consider the inherent risk of natural climatic constraints on water availability, but physical conditions related to slope, aspect, and soil depth and texture should be considered in forest management since they could modify regional conditions. Also, using hydrological modeling, we found that the proportion of native forest and a system of mosaic management could play an important role in the reduction and regulation of water use. Based on these results, a framework considering environmental factors and management options was built in order to understand a range of expected effects. Finally, we discuss alternative forest plantation management to avoid negative effects and optimize water ecosystem services.

Key words: Eucalyptus; fast-wood plantation; water use; hydrological effects; pulp and paper industry

[38]

Assessing potential benefits of natural forest cover increase to hydrological processes in agricultural landscapes at southeast Brazil

Silvio F. B. Ferraz[1], Paulo Guilherme Molin[2], Walter de Paula Lima[1], Carla Cristina Cassiano[2], Ricardo Taniwaki[2], Yuri Forte[2]

[1]University of São Paulo, Brazil
[2]Forest Resources Graduate Program, University of São Paulo, Brazil

Abstract:

The Atlantic forest in Brazil is entering a transition process where socio-economic and policy factors are leading to forest restoration action in order to conserve water, biodiversity and ecological processes. Using experimental data and hydrological modeling, we will discuss the role of current and future forest cover on ecosystem services related to water in agricultural landscapes of southeast Brazil. Historical images were used to understand forest cover dynamics at pasture and sugarcane matrices and their environmental and socio-economic drivers in the Piracicaba river basin. Using past dynamics and drivers, future scenarios of forest change were generated. We assessed the role of tropical forest fragments on delivering environmental services related to water and aquatic ecosystem. Based on these results, it was possible to develop a landscape ecohydrological management proposal, including the strategic design of forest conservation and restoration for agricultural landscapes. A pilot study in the Piracicaba river basin culminated with a multi-scale methodology to define priority sites for restoration, considering their natural physical conditions as well as political and social aspects. Considering the methodology developed, distributed hydrological modeling was used to assess the performance of future restoration scenarios on ecosystem services delivery. Results showed that natural forest extension is increasing but there is uncertainty about future maintenance of actual services offered. We conclude that technical knowledge of the role of forests on different ecosystem services based on experimental data and hydrological modeling seems to be essential for better forest restoration planning for targeting water and aquatic environment conservation. Financial Support of FAPESP: 2013/22679-5.

Key words: landscape ecology; Atlantic forest; sugarcane; ecosystem services; hydrological modelling

[39]

Stream discharge measurements using an automated salt dilution system in a hyper-maritime watershed on British Columbia's central coast

Bill Floyd[1,2], Maartje Korver[3], Colby Owen[4], James McPhail[4]

[1] Ministry of Forests, Lands and Natural Resource Operations, Canada
[2] Department of Geography, Vancouver Island University, Canada
[3] University of Amsterdam, The Netherlands
[4] Hakai Energy Solutions, Canada

Abstract:

With increasing pressure on water resources from resource development and climate change, it has never been more important to expand hydrometric networks. Manually measuring stream discharge is a fundamental component of rating curve development at most hydrometric stations in BC and Canada. Traditionally, this requires routine visits to the station in an effort to measure discharge across the entire range of stream stages, to develop rating curves and monitor stream flow continuously. In watersheds where snow and glaciers dominate, measuring moderate to high flows has a measure of predictability associated with snow-melt freshets. However, in watersheds with peak flows driven by rain and rain-on-snow events, being on site to measure high flows is operationally difficult due to the limitations of weather forecasting and the rapid response of coastal watersheds. These characteristics make it difficult to build discharge rating curves that adequately describe moderate to high stream flows. In addition, many watersheds of interest are in remote locations, making routine access prohibitively expensive. These limitations highlight the need for methods to remotely measure stream discharge. A prototype version of an automatic salt dilution (auto-salt) stream discharge system has been installed at the Hakai Institute, a long-term, coastal margin observatory with an extensive real-time weather and hydrometric network. Between September and December 2014, more than 40 moderate to high discharge measurements were collected. The design of the system will be presented, along with an assessment of error in calculating stream flow using this method. Additional results will be presented demonstrating how auto-salt measurements improved stage discharge rating curves.

Key words: salt dilution; rating curves; hydrometric; rain-on-snow; discharge

[40]

River discharge regulates relationships between catchment landscape components and C:N:P ratios in streams of the Xitiao River watershed, China

Changjun Gao[1], Ping Zhou[1], Lijuan Cui[2], Demin Zhou[3]

[1]Guangdong Academy of Forestry, No. 233, Guangshan 1st Road, Tianhe District, Guangzhou 510520, P.R. China
[2]Institute of Wetland Research, Chinese Academy of Forestry, No. 1, Dongxiaofu, Haidian District, Beijing, 100091, P. R. China
[3]Key of Environment Resource and GIS, Capital Normal University, No. 105 North-west 3rd Ring Road, Haidian District, Beijing 100048, China

Abstract:

C:N:P ratios have important implications for the composition and functioning of lotic ecosystems. River discharge has been regarded as one of critical drivers for dynamics of C:N:P ratios in streams and rivers. However, the river discharge controls on variations in anthropogenically altered stream water C:N:P ratios remains largely unknown. To understand the hydrologic controls on nutrient ratios in these streams, we firstly examined temporal patterns in relationships between stream water C:N:P ratios and catchment characteristics in fourteen streams in the Xitiao River watershed, China, and then assessed whether the variations could be explained by changes in hydrological conditions over the course of a year. Results indicated that stream water C:N:P ratios were significantly correlated to several catchment properties when averaged across the study period by stream. In addition, the strength of the relationships between nutrient ratio and landscape components was significantly altered by changes in hydrologic conditions of the Xitiao River watershed. This analysis demonstrated that the balance of element fluxes through these human-dominated streams was strongly affected by catchment properties, but the effects were sensitive to river discharge. These results may help us understand the effect of river discharge on nutrient transport in lotic ecosystems, and may provide a theoretical basis for managers to minimize adverse effects of hydrological alterations and catchment land use change on receiving streams.

Key words: river discharge; landscape; hydrologic condition; nutrient ratios; human-dominated catchment

[41] Poster

Transpiration and canopy conductance variations of shelterbelt in an arid inland river basin of northwest China

Guangyao Gao[1], Qin Shen[1], Bojie Fu[1], Yihe Lü[1]

[1]State Key Laboratory of Urban and Regional Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing, China

Abstract:

The knowledge of plant water use characteristics under changing environmental conditions is essential for ecosystem management and water resources distribution in arid areas. This study was conducted to quantify variations in transpiration and canopy conductance in a shelterbelt in the middle of the Heihe River Basin, China. Sap flow of eight Gansu Poplar trees (*Populus gansuensis*) with different diameters at breast height (DBH) was measured over three consecutive growing seasons (2012-2014). The evapotranspiration of groundwater via plant use was estimated by the White method, with diurnal water table fluctuations. Results showed that mean sap flow density varied between 30.62 ±11.44 and 101.88 ±28.98 kg m^{-2} h^{-1}, and it increased linearly with the DBH. Variations of sap flow density were mainly controlled by meteorological factors in addition to water table depth. Average stand transpiration during the growing season was about 4.85 mm day^{-1}, and it had a logarithmic relationship with reference crop evapotranspiration. Precipitation increased stand transpiration, but not at a statistically significant level ($p>0.05$). The recharge of soil water by irrigation significantly accelerated stand transpiration ($p<0.05$). Stand transpiration and canopy conductance increased by 27% and 31%, respectively, when soil water conditions changed from dry to wet. Canopy conductance decreased logarithmically with vapor pressure deficit, whereas there was no apparent relationship between canopy conductance and solar radiation. The sensitivity of canopy conductance to vapor pressure deficit decreased under dry soil conditions. Groundwater evapotranspiration (0.6-7.1 mm day^{-1}) was linearly correlated with stand transpiration (1.1-6.5 mm day^{-1}) ($R^2 = 0.71$). During the drought period, approximately 80% of total stand transpiration came from groundwater evapotranspiration. This study highlighted the critical role of irrigation and groundwater for shelterbelts, and might provide the basis for the development of water requirement schemes for shelterbelt growth in arid inland river basins.

Key words: shelterbelt transpiration; canopy conductance; soil drought; groundwater variation; Heihe River basin

[42] Poster

Effects of land use on the partitioning of precipitation into evapotranspiration, surface runoff and soil water recharge in eastern Madagascar

Chandra Prasad Ghimire[1], H.J. (Ilja) van Meerveld[2], Bob Zwartendijk[2], Maafaka Ravelona[3], Herintsitohaina Razakamanarivo[3], Maciek Lubczynski[1], L.A. (Sampurno) Bruijnzeel[4]

[1]University of Twente, Faculty of Geo-Information Science and Earth Observation (ITC), Enschede, The Netherlands
[2]University of Zurich, Department of Geography, Hydrology and Climate, Zurich, Switzerland
[3]Laboratoire des Radio-Isotopes, Antananarivo, Madagascar
[4]VU University Amsterdam, Critical Zone Hydrology Group, Amsterdam, The Netherlands

Abstract:

While tropical deforestation continues at an alarming rate, some cleared land is eventually abandoned and replaced by natural regrowth or is actively replanted, so that secondary forests are now ubiquitous across the tropics. Reforestation is promoted for a wide range of benefits, including carbon sequestration, rehabilitation of degraded land and streamflow regulation. However, how the reforestation of degraded land affects runoff generation mechanisms and streamflow is still poorly understood, as most experimental studies have been conducted in non-degraded catchments. Evaporative losses (transpiration and interception) likely increase after reforestation, while infiltration rates are expected to increase and surface runoff occurrence to decrease as a result of improved soil hydraulic conductivity with time after reforestation. The net result on soil and groundwater recharge and water yield of these two opposing effects is poorly documented, but likely to be site-specific. To investigate this further, research plots were installed in an old-growth forest, a young secondary forest and a degraded grassland in the high rainfall zone of eastern Madagascar to allow quantification of rainfall interception (wet canopy evaporation measured using 66 throughfall gauges per forest site), transpiration (dry canopy evaporation measured using 12-21 TDP sapflow sensors per forest site) and surface runoff (2-3, 3 x 10 m runoff plots per site). This poster documents the experimental design and initial results for the 2014/15 rainy season, and highlights the effects of land cover on the partitioning of precipitation into the chief vertical and lateral fluxes.

Key words: surface runoff; transpiration; interception; water balance; Madagascar

[43]

Introducing a new coastal margin observatory in the Pacific coastal temperate rainforest

Ian Giesbrecht[1], Ken Lertzman[2,1], Bill Floyd[3,1], Suzanne Tank[4,1], Gordon Frazer[5,1], Allison Oliver[4,1], William Mohn[6,1], Colleen Kellogg[6,1], Andrew Trant[7,1], Kira Hoffman[7,1], Thierry Heger[6,1], Paul Sanborn[8,1], Brian Hunt[6,1], and Steven Hallam[6,1]

[1]Hakai Institute, Calvert Island, BC, Canada
[2]Simon Fraser University, Burnaby, BC, Canada
[3]BC Ministry of Forests, Lands and Natural Resource Operations *and* Vancouver Island University, Nanaimo, BC, Canada
[4]University of Alberta, Edmonton, AB, Canada
[5]GWF LiDAR Analytics, Sidney, BC, Canada
[6]University of British Columbia, Vancouver, BC, Canada
[7]University of Victoria, Victoria, BC, Canada
[8]University of Northern British Columbia, Prince George, BC, Canada

Abstract:

The export of terrestrial materials from coastal watersheds influence marine ecosystems and carbon budgets across the globe, yet much is unknown about the fundamental processes of land-sea carbon cycling or system response to climate change. On an outer-coast island near the center of the Pacific coastal temperate rainforest (PCTR), the Hakai Institute has developed a long-term coastal margin observatory to examine the flux of terrestrial materials from land to sea –origins, pathways, processes and food web consequences – in the context of long-term environmental change. Through this lens, we trace the coupling of terrestrial carbon and water from the soils of forest and wetland ecosystems through streams to the near-shore ocean. Beginning in 2013, we established a year-round sampling program and sensor network to quantify, at high temporal resolution, the amount and character of terrestrial exports from seven focal watersheds. Within the study area, the terrestrial environment is ecologically and physically diverse – a mosaic of forest, wetlands, forested wetlands and exposed bedrock – and our initial results show that different watersheds and ecosystem types behave differently as exporters of terrestrial materials. We use airborne LiDAR data to evaluate landscape controls on forest vegetation height, and test the hypothesis that soil drainage quality exerts a dominant influence on forest productivity and biomass on the outer coast. We are examining the role of microbial communities in processing organic matter across multiple scales: within soil profiles, across a soil drainage gradient, and across the broader land-sea gradient. In this presentation, we provide an overview of a new long-term multi-disciplinary investigation of the hydrological, biogeochemical and ecological processes that link PCTR watersheds with the carbon balance and food web of the coastal ocean.

Key words: dissolved organic carbon; forested wetlands; marine food webs; LiDAR; sensor network

[44] Poster
Erosion and sediment control practices for resource roads and stream crossings: A practical operations guide

Clayton Gillies[1]

[1]FPInnovations, Canada

Abstract:

Natural resource industries are continuously looking to improve their environmental performance and maintain their Social License in order to retain market share and, more recently, retain public trust in their management of the land base. The protection of water and aquatic habitats is a key element of these management plans. In response to these needs, FPInnovations has developed a practical operations handbook on erosion and sediment control entitled "Erosion and Sediment Control Practices for Forest Roads and Stream Crossing: A Practical Operations Guide". This handbook provides background for understanding the modes of erosion and the importance of understanding these modes in order to better prevent erosion. It also provides practical strategies for preventing erosion and containing sediment using best management practice recommendations and expertise from field practitioners.

The focus of the handbook is on soils that have been exposed due to resource road construction activities, where the main issue is preventing exposed soils from eroding at unacceptable levels and mobilized sediment from reaching streams and water bodies. The emphasis needs to be, however, on preventing erosion rather than containing mobilized sediment. The handbook is aimed at resource road construction crews and their supervisors; however, environmental monitors and harvest planners will also find the examples extremely helpful. The handbook utilizes clearly worded text and highly illustrative schematics to present important concepts in distinct but integrated learning modules.

FPInnovations has disseminated the handbook to the forest industry in Canada, and used it to train field practitioners. The handbook has become well recognized and a Canadian industry standard: e-lectures through University, webinars, and over 50 workshops reaching 1000+ practitioners. The remediation training in this handbook is well aligned with a recent BC government initiative which provides industry with water quality assessment procedures and has been jointly presented in recent workshops.

Key words: erosion; sediment control; water quality

[45]

Impacts of historical channel modification and water extraction (ground and surface) on surface water resources in Cowichan River, British Columbia

Neil Goeller[1], Sylvia Barroso[1], Robin Pike[2]

[1]BC Ministry of Forests Lands and Natural Resource Operations, Water Protection. Nanaimo, BC, Canada
[2]BC Ministry of Environment, Water Protection and Sustainability Branch. Victoria, BC, Canada

Abstract:

Cowichan River is an important resource in the Cowichan valley, on the west coast of North America. The river was designated a Canadian Heritage River in 2003, and is an international indicator stream for Pacific salmon. Pressures and demands on the river are substantial. In addition to providing habitat to many different fish species, the river provides water for domestic use, industrial operations and effluent treatment, and is a key tourism and recreation location on Vancouver Island.

Historic channel modifications have extensively altered the river channel morphology. Industrial operations regulate river flow and extract large volumes of surface water. Two effluent discharges are located on the river, one at Lake Cowichan and a second nearer the estuary. A groundwater well field on the floodplain supplies water to two municipalities and four fish hatcheries. Groundwater withdrawals from the underlying aquifers are substantial, and high production wells are located in close proximity to the river channel.

A three year study was conducted to evaluate the effect of groundwater withdrawals on surface water flows in Cowichan River. The study investigated the connectivity between surface and groundwater, and the long term implications to water use and water management on a regulated river and the adjacent aquifers. This presentation provides an overview of the disturbance history of the Cowichan River, and details the approaches, challenges and results of the investigation of groundwater-surface water interactions.

With the introduction of groundwater licensing in BC, this study plays a critical role in providing science to support policy development under the new BC Water Sustainability Act.

Key words: Cowichan River; groundwater extraction; surface water; groundwater-surface water interaction

[46]

How did runoff and stream temperature responses after 50% thinning differ among nested observations of headwaters?

Takashi Gomi[1], Bui Xuan Dung[2], Marino Hiraoka[1], Mitsuru Oohira[1], Yuichi Onda[3]

[1]Tokyo University of Agriculture and Technology, Tokyo, Japan
[2]Vietnam Forestry University, Vietnam
[3]University of Tsukuba, Japan

Abstract:

We investigated runoff and stream temperature response after 50% thinning in nested headwater catchments draining Japanese cypress (*Cryptomeria japonica*) and cedar (*Chamaecyparis obtusa*) forests. Our nested observations permitted examination of scaling effects on runoff and stream temperature responses after forest thinning. Fifty percent of the stems in a 17 ha treatment catchment were removed by strip thinning, and a 9 ha catchment remained untreated as a control. We installed 4 nested gauging stations in the treatment and control catchments, with drainage areas ranging between 3 and 10 ha. Both runoff and stream temperature at each gauging station was analyzed using the paired-catchment approach for the pre- (April 2010 to May 2011) and post-thinning periods (June 2011 to December 2012). Paired-catchment analysis revealed that annual runoff increased 230-650 mm, with the greatest changes observed at the lowest station followed by the head-most gauging station. Increased runoff volume was associated with both contributions from deeper groundwater sources as well as from overland flow on skid trails. Stream temperature response varied between gauging stations depending on the occurrence of surface and subsurface flow interactions. Our findings showed that internal hydrological flow pathways and associated changes in runoff components due to forest thinning affect the order of magnitude of runoff and stream temperature responses in different locations of nested observations.

Key words: forest thinning; paired-catchment analysis; runoff responses; stream temperature; scaling effects

[47]

Hydrologic risk assessment in beetle-attacked southern interior BC watersheds

Bill Grainger[1], David Huggard, Alan Bates[2]

[1]Grainger and Associates Consulting Ltd., Canada
[2]Streamworks Consulting Inc., Canada

Abstract:

In many southern interior BC watersheds, mountain pine beetle and spruce beetle infestations have caused significant forest mortality. To assist forest managers making salvage harvesting decisions and water users potentially impacted by those decisions, hydrologic risk assessments have been completed in 32 watersheds. Potential risks to watershed ecosystem values (fish habitat) and social values (water supply quality, quantity and timing) were evaluated for different proposed forest management options.

Numerical modeling of the relative change in water availability after either retention of beetle-attacked forests or clearcut salvage harvesting showed markedly different results depending on the types of affected forests and management histories. Differences in individual watershed physiography, geomorphology and disturbance histories resulted in various runoff routing, peak flow and sediment effects, and channel sensitivities to flow changes. All of these processes combine into a single hydrologic hazard. Most watersheds have significant ecological and/or social values. The many possible combinations of different hazard processes and consequence values results in a wide range of risk outcomes, confirming the need for detailed hydrologic risk assessments.

Nevertheless, some regional trends were observed. In mixed-species mid-elevation forests supplying water to major urban centres in the Okanagan watershed, extensive clearcut salvage harvesting can result in higher risks compared to retention of MPB-attacked forests. In the western and northern parts of the study area, unharvested heavily-attacked pine forests can produce significant risks. Here, some salvage harvesting and replanting can minimize long term risks resulting from slower natural forest regrowth and hydrologic recovery. In these types of watersheds, however, clearcut salvage harvesting of spruce beetle attacked, higher elevation mixed spruce and fir forests has a greater hydrologic impact than forest retention, and can result in significant increases in already high hazards and risks. These latter findings could impact already limited post-MPB timber supplies.

Key words: watershed; risk assessment; beetle infestation; salvage harvest; forest retention

[48]

Water-use and growth of indigenous tree species in South Africa

Mark B. Gush[1], Peter J. Dye[2], Tatenda Mapeto[3], Harrison Pienaar[1]

[1]CSIR, Natural Resources & Environment, Stellenbosch, South Africa
[2]University of Witwatersrand, South Africa
[3]Nelson Mandela Metropolitan University, South Africa

Abstract:

Products and services from indigenous tree species and forests are sought after in South Africa, due to their quality, durability, economic value, cultural significance and aesthetic appeal. However, their slow growth rates and limited extent render them unable to meet the timber needs of a developing economy. This necessitated the establishment of a plantation forest industry using fast-growing introduced tree species. While the benefits of plantation forests are undisputed in terms of timber production, income generation and job provision, these come at some environmental cost, including an impact on water resources. Resultant research led to progressive regulation of the industry due to water-use concerns. With a view to expansion of forested areas in a manner that utilises water as sustainably as possible, there has been interest in the water-use efficiency of indigenous tree species. This paper presents results of a 6-year study solicited and funded by the Water Research Commission in South Africa to explore whether indigenous tree species use less water than introduced plantation tree species, and whether they use that water more efficiently in terms of biomass accumulation. Transpiration and total evaporation measurements were used to derive water-use volumes for individual indigenous tree species and mixed species indigenous forests, over periods ranging from 12 to 24 months. Simultaneously observed annual utilisable stem biomass increments were used to calculate water-use efficiency for comparison against existing data for introduced plantation tree species. Results showed that indigenous tree species used less water than the introduced plantation trees, but exhibited similar water-use efficiencies. The study confirms the important role of indigenous trees from an ecohydrological perspective, and the findings have wider scale applicability in fields such as forest restoration, erosion control, replacement of invasive alien species and multiple-use indigenous tree wood-lots, particularly where water-conservation is a priority.

Key words: forests; sap flow; transpiration; water-use efficiency; hydrology

[49]

Climate effect on tree-ring widths of *Fagus orientalis* in the Caspian Forests of northern Iran

Malek Haghshenas, Mohammad Reza Marvi Mohadjer, Pedram Attarod, Shirin Varkuhi, Jeff Feldhaus

Abstract:

This study aims to understand the impacts of climate factors on annual growth variations of oriental beech (*Fagus orientalis* Lipsky) at the Kheyrud Forest Research Station located in the Caspian forests of northern Iran. Eighteen disc samples were randomly collected from altitudes of 1038 to 1152 m above the Caspian Sea. Treerings were measured using TSAP-win software and a LINTABII Machine. Since false and missing rings are common in beech trees, skeleton plots were created to enhance crossdating accuracy. Chronologies were observed for a total of fifteen samples. Rainfall and air temperature data was obtained for the Nowshahr Meteorological Station, located near the study sites. Results showed a significant correlation between mean annual air temperature and radial growth (R = 0.54). During the growing season, August temperature showed a significant correlation with treerings (R = 0.41), while the strongest association was observed in the previous December (R = 0.44) and the weakest association was found in February (R = 0.31). Excluding March (R = 0.33), there appeared to be no significant correlation between precipitation accumulated during and prior to the growing season and treerings. In addition to oriental beech, there are many other species important to this region that may be sensitive to increasing temperatures.

Key words: Caspian forests; crossdating; dendrochronology; Fagus orientalis Lipsky; treering

[50] Poster
Transpiration, canopy interception and stem flow according to different spacing and genotypes in a high productivity eucalypt plantation

Rodrigo Hakamada[1], Silvio Frosini de Barros Ferraz[2], Robert Hubbard[3], Jose Luiz Stape[4], Cristiane Lemos[5], Gabriela Trindade Pires[2]

[1]Forest Resources Graduate Program, University of Sao Paulo, Brazil
[2]University of Sao Paulo, Brazil
[3]USDA Forest Service, Rocky Mountain Research Station, U.S.A.
[4]North Carolina State University, U.S.A.
[5]International Paper do Brasil, Mogi Quaçu, Brazil

Abstract:

Eucalypt plantations cover about 20 M hectares worldwide and are expected to expand mainly into marginal areas where dry conditions can lead to water conflicts. One of the main reasons for the rapid expansion is its high wood growth, which may also affect water balance components. Genotypes and silviculture practices, such as correct plant spacing, are key factors that regulate carbon and water tradeoffs on a stand scale, but few studies have been conducted especially in highly productive clonal plantations. Our goal in this paper was to study the effect of spacing and genotypes on transpiration, canopy interception and stem flow in a Eucalyptus clonal plantation. The assay used is part of a larger study (TECHS project - Tolerance of Eucalyptus Clones to Hydric and Thermal Stresses) located in flat Oxisol soil in southeast Brazil. Treatments are two hybrid clones (*E. grandis* x *E. camaldulensis – grancam* and *E. grandis* x *E. urophylla – urograndis*) and four densities ranging from 600 to 3.000 stem ha^{-1}. Evaluations of wood growth, transpiration by using Granier method, canopy interception and stemflow were done during a full year, for tree ages 21 to 33 months old, when precipitation was 738 mm. Independent of genetics, growth increased with increasing density and transpiration, varying 515-595 mm in wider spacing to 735-978 mm in tighter spacing. Interception was also higher in tighter spacing, representing 18-22% of precipitation compared to 13-14% in wider spacing. Stem flow represented 2-5% of precipitation in denser spacing and 1-2% in broader spacing. When density was higher than 1.250 and 1.750 stems ha^{-1} in *urograndis* and *grancam* clones, respectively, the water balance was negative. On a stand scale, results show both genetics and spacing should be used as silviculture tools to better manage the tradeoff between wood growth and water production.

Key words: water productivity; silviculture practices; stocking level; Eucalyptus clones; water balance

[51]

Evaluation of complex relationships between large historic wildland fires and streamflow in watersheds across the conterminous U.S.

Dennis W. Hallema[1], Ge Sun[1], Peter V. Caldwell[2], Steven P. Norman[3], Erika C. Cohen[1] Yongqiang Liu[4], Steven G. McNulty[1]

[1]USDA Forest Service Southern Research Station, 920 Main Campus Drive, Venture Center II Suite 300, Raleigh, NC, U.S.A. 27606
[2]USDA Forest Service Southern Research Station, 3160 Coweeta Lab Road, Otto, NC, U.S.A. 28763
[3]USDA Forest Service Southern Research Station, 200 W.T. Weaver Blvd., Asheville, NC, U.S.A. 28804
[4]USDA Forest Service Southern Research Station, 320 Green Street, Athens, GA, U.S.A. 30602

Abstract:

Wildland fires in western U.S. ponderosa pine and mixed-conifer forests in the period before 1900 were often polycyclic low intensity understory fires, while severe crown fires and stand replacement wildfires were more common in pine stands in the coastal southeastern U.S. Since large-scale fire suppression came into practice in the early 1900s, forest densification and fuels build up have increased, presently causing higher fire intensities and greater fire risk to the growing population at the wildland-urban interface. Current knowledge of the first-order effects on stream flow and water supply is very limited, and therefore we explored the characteristics of 20 large wildland fires observed in the past 15 years, and evaluated the complex relationships with stream flow in the years before and after these events. We combined long stream flow records with the Monitoring Trends in Burn Severity (MTBS) database and a 236x236 m resolution Digital Elevation Model (DEM), and were thus able to select more than 300 watersheds (area >10 km^2) burned more than 10% between 1984 and 2014. This selection was further narrowed down to include a variety of fire regimes, geographical locations, ecosystems and fuel management types. The final set of 20 watersheds were analyzed for changes in flow regime after a major fire. In the case of the Biscuit Complex Fire in 2002 that burned 73.6% of a 707 km^2 watershed in southwest Oregon, double mass analysis revealed that the wildland fire has significantly ($p=0$) altered the natural flow regime. We also examined the sensitivity of water yield response to wildland fires across the conterminous US using a monthly water balance model (WaSSI) and identified watersheds that may be most vulnerable to impacts from wildland fires.

Key words:

[52] Poster

Evaluating the effects of nitrogen deposition on forest soil carbon cycle in northeast region of China

Longfei Hao[1], Qingcheng Wang[1]

[1]School of Forestry, Northeast Forestry University, No. 26, Hexing Road, Xiangfang District, Harbin, Heilongjiang, 150040, China

Abstract

Evaluating the effects of nitrogen deposition on forest soil carbon cycle is important for estimating regional carbon budgets and their responses to environmental changes. In this study, two-year nitrogen deposition experiments have been conducted with four different treatments, including control (CK, 0 g m^{-2} a^{-1}), low nitrogen (L, 5 g m^{-2} a^{-1}), moderate nitrogen (M, 10 g m^{-2} a^{-1}) and high nitrogen (H, 15 g m^{-2} a^{-1}) applications in four forest stands (*Pinus koraiensis*, *Larix gmelinii*, *Fraxinus mandschurica*, and *Betula platyphylla*). Results indicated that soil organic carbon was significantly higher (P<0.05) in the L treatment among different forest stands (CK<H<M<L). The L treatment increased carbon release rates during leaf and root litter decomposition, and the rate of soil respiration was significantly greater (P<0.05). These results showed that the largest increase in soil carbon content occurred under low nitrogen applications, because inputs exceeded losses. Root respiration was restricted during nitrogen application, as root biomass decreased with increasing nitrogen applications. Microbial respiration under the L treatment was 38.9% greater than under CK (P<0.05), although soil respiration was significantly higher for the L treatment (P<0.05). Results showed that microbial respiration was a dominant component of the soil respiration process. In addition, significant correlations were found between N/P stoichiometry characteristics and the dynamic index of the soil carbon cycle (P<0.05). Soil carbon increased with N/P. Therefore, soil N/P is an important indicator of soil carbon.

Key words: nitrogen deposition; ecological stoichiometry characteristics; carbon cycle; correlation analysis

[53] Poster
Hydrological responses to urbanization in the urban–rural interface in Nanjing, China

Lu Hao[1], Ge Sun[2], Yongqiang Liu[3], Mengsheng Qin[1], Chong Liu[4], Hong Qian[1]

[1]The International Center for Ecology, Meteorology, and Environment (IceMe), Jiangsu Key Lab of Agricultural Meteorology, Nanjing University of Information Science and Technology, Nanjing 210044, PR China
[2]Eastern Forest Environmental Threat Assessment Center, Southern Research Station, USDA Forest Service, Raleigh, NC 27606, USA
[3]Center for Forest Disturbance Science, Southern Research Station, USDA Forest Service, Athens, GA 30602, USA
[4]State Key Laboratory for Information Engineering in Surveying, Mapping and Remote Sensing, Wuhan University, Wuhan, 430079, PR China

Abstract:

Contemporary urbanization-associated land conversions profoundly affect hydrologic conditions at the urban – rural interface (URI) in many parts of the world. Understanding regional ecohydrological responses to the anthropogenic forcing of land use/land cover change (LUCC) and human activities (such as urbanization, population rise, land conversions, water withdrawals, reservoir construction) in the context of climate change is critical for future URI planning, water resource management, and sustainable development. The Qinhuai River is one of the tributaries of the Yangtze River that runs through Nanjing, a mega city in southern China. Qinhuai River basin provides important functions to more than 8 million residents, including drought/flood prevention, crop irrigation, recreation, tourism and emergency drinking water supply. This study is aimed to answer two questions: 1) Has LUCC significantly changed streamflow characteristics during the past three decades? and 2) What are the contributions of LUCC and climate to the hydrologic responses? The variability, extremes, and trends of precipitation, temperature, droughts, floods and streamflow were analyzed using nonparametric Mann-Kendall tests and the double mass curve technique. A water balance model (WaSSI) was used to model annual evapotranspiration (ET), streamflow and drought indices for the entire basin. The LUCC and associated changes in ET and leaf area index were investigated using MODIS remote sensing products. Results indicate that historical streamflow and ET in the study basin has been altered substantially, mostly due to LUCC. Ongoing large scale land conversion at the URI, including converting wetlands (e.g., rice paddy fields) to urban use, will likely elevate stormflow volumes and aggravate flooding risks during the summer monsoon season.

Key words: land use/land cover change; stream flow; climate change; evapotranspiration; urbanization

[54]

Effects of clearcut logging on aquatic invertebrates in headwater streams of Upper Penticton Creek, British Columbia

Brian A. Heise[1]

[1]Department of Natural Resource Sciences, Thompson Rivers University, Kamloops, British Columbia, Canada

Abstract:

Headwater streams in interior British Columbia watersheds contain aquatic insects and other invertebrates critical to forest and stream biodiversity. These invertebrates also drift downstream to feed trout, and other fish. As logging practices in B.C. allow the harvesting of trees right up to the edge of headwater streams, I was interested in whether clearcut logging decreases abundance and community structure of invertebrates in these streams.

I examined the effects of logging on three streams in the Upper Penticton Creek Watershed. Dennis Creek was monitored for 1 year pre-harvest, and 4 years post-harvest, 241 Creek was studied for two years pre-, and two years post-harvest, and 240 Creek served as the control (unlogged) stream. Artificial substrate baskets containing gravel were placed in all streams to monitor aquatic invertebrate communities.

Both logged creeks experienced significantly increased numbers of Ephemeroptera, Diptera, and total insects, and a decrease in the proportion of shredders. Genus richness increased in 241 Creek, but was unchanged in Dennis Creek. The EPT index increased in 241 Creek, but the EPT/D index decreased in both clearcut streams, indicating a decrease in the health of the invertebrate community. Overall, logging appeared to increase the total amount of invertebrates in streams, but altered the community structure and processing of organic matter.

Key words: aquatic invertebrates; clearcut logging; headwater streams

[55] Poster

Responses of streamflow to forest thinning in mature coniferous plantation forests: One-year analysis of pre- and post-treatments

Marino Hiraoka[1], Takashi Gomi[1], Yuichi Onda[2], Makiko Tateishi[3], Tamao Kasahara[4], Kyoichi Otsuki[4]

[1]Tokyo University of Agriculture and Technology, Japan
[2]University of Tsukuba, Japan
[3]Kyoto University, Japan
[4]Kyushu University, Japan

Abstract:

We examined the response of streamflow to a 50%-intensity thinning with stem density in three headwater catchments draining 40- to 50-year Japanese cedar and Japanese cypress plantation forests. Drainage areas ranged from 3.4 to 17.1 ha. Strip thinning was conducted in one catchment (ST) and random thinning was conducted in two catchments (RT and RF). The ST and RT catchments are adjacent and underlain by sedimentary rock. The RF catchment is underlain by granite. By comparing flow-duration curves pre- and post-thinning, daily streamflow post-thinning was 1.72 and 1.98 times greater during high- and low-flow conditions than pre-thinning in ST, while minor changes in flow duration curves occurred during high- (1.41 times) and low-flow (0.48 times) conditions in RT. Because the stem removal in terms of volume of RT (24%) was lower than that of ST (46%) despite the same density of stem removal, random thinning did not alter canopy interception and transpiration enough to detect streamflow changes. In RF, the change in daily streamflow was 1.97 times during low-flow conditions, while no change of the flow duration curve was observed during high-flow condition (0.85 times). Although the stem removal in terms of volume in RF (41%) was similar to ST, obvious changes in the flow duration curve were not detected. This result suggested that streamflow under wet conditions cannot always respond to stem removal within one year, and that changes detected during dry conditions may be due to deep percolation and groundwater recharge. To consider this implication, changes in internal flow processes of a catchment due to a thinning treatment will be discussed.

Key words: streamflow; forest thinning; flow duration analysis

[56]

An indicator approach to watershed assessments: Water use and shale gas development in a forested landscape within the Simonette watershed, Alberta

Faye Hirshfield[1], Axel Anderson[1], Ryan MacDonald[2], Michael Wagner[3], Jesse Kirillo[4], Melonie Zaichkowsky[5]

[1]University of Alberta, Edmonton, Alberta, Canada
[2]Foothills Research Institute, Hinton, Alberta, Canada
[3]Alberta Environment and Sustainable Resource Development, Calgary, Alberta, Canada
[4]Talisman Energy, Edson, Alberta, Canada
[5]CANFOR, Edson, Alberta, Canada

Abstract:

Forested watersheds are known to provide many ecosystem services, including clean regulated water to downstream users and the support of critical habitats for species of concern. Like many different parts of the world, areas of Alberta and British Columbia (western Canada) have critical forested watersheds with overlapping land uses and different uncoordinated tenures under various levels of regulation. Specifically, the Simonette watershed in the Foothills region of Alberta has heavy development from both hydraulic fracturing and harvesting as part of Canfor's Forest Management Unit. The science and assessment techniques used in forested watersheds are often tailored for one dominant land use, such as forestry, agriculture, oil and gas and mining. For example, the equivalent clearcut area (ECA) method is used to measure change in the hydrologic function of a watershed; however, variations in local climate, basin morphology and underlying geology can also affect flow variability within a watershed. For this project, we introduce an indicator approach to integrated watershed assessment and management. While inherent uncertainty exists in defining indicators, the overarching philosophy in using indicators for integrated watershed assessment should highlight whether a deeper investigation of watershed processes is required.

For this study, we use information for the Simonette Watershed and highlight the indicator of water quantity to identify pressures on water use within the basin. Currently there are concerns around impacts to fish species at risk in the Simonette Watershed and diversion of water to support hydraulic fracturing development. We quantify total water use across all sectors in the Simonette, and compare them against the minimum instream flow thresholds set by the Government of Alberta. We use water availability data along with area disturbed by hydraulic fracturing and forestry as input into a hydrological model, in order to forecast potential change in future water availability under various harvest and shale gas development scenarios.

Key words: water use; hydraulic fracturing; water availability; hydrologic modelling

[57] Poster

Spatial variations in concentration and nitrogen and oxygen stable isotopes of river nitrate in a hilly and mountainous area, western Japan

Jun'ichiro Ide[1], Somura Hiroaki[2], Takashi Nakamura[3], Yasushi Mori[2], Ikuo Takeda[2], Kei Nishida[3]

1Institute of Decision Science for a Sustainable Society, Kyushu University, Japan
2Faculty of Life and Environmental Science, Shimane University, Japan
3International Research Center for River Basin Environment, University of Yamanashi, Japan

Abstract:

Anthropogenic nitrogen inputs to terrestrial ecosystems can result in an increased concentration of nitrate in river water. It was reported that nitrate concentrations have been gradually increasing in rural rivers of western Japan, based on 15-year observations. This could be attributed to the fact that long-range transport of nitrogen from East Asia affects nitrogen cycles in forest ecosystems, resulting in increases in nitrate loadings from forests to the downstream rivers. It was also reported that forest land use could be the dominant source contributing to increases in nitrate concentrations in rural rivers under high flow conditions. On the other hand, river nitrate concentration can vary within a river channel because of spatial variations in hydrological and biogeochemical processes, such as denitrification that often occurs in river sections with gentle slopes. This variation should be considered in assessing the effects of land use on nitrate concentrations in rivers. However, few studies have focused on the effects of hydrological conditions on spatial variations in nitrate concentration in a river in steep terrain. In this study, we addressed this gap by collecting river water samples at seven sites along the main channel of rural river in a hilly and mountainous area of western Japan, and analyzed nitrate concentration and nitrogen and oxygen stable isotopes. Results will be reported.

Key words: antecedent moisture conditions; diffuse pollution; Hii River; low birth rate and longevity; river discharge

[58]

Parameterization of SCS curve number on small forested watersheds from rainfall-runoff data

Sangjun Im[1], Song Eu[1], Eun Jae Lee[1], Hyung Tae Choi[2]

[1]Dept. of Forest Sciences, Seoul National University, Korea
[2]Korea Forest Research Institute, Seoul, Korea

Abstract:

Accurate estimation of runoff volume from forested watersheds is important for effective design of hydraulic structures in mountain streams, as well as for managing stormflow during rainy the season. The curve number approach, developed by the Soil Conservation Service (SCS) of the U.S. Department of Agriculture to predict direct runoff in ungauged watersheds, has been widely applied since the mid-1950s in surface water hydrology. The method represents variation in runoff with one parameter, called the "Curve Number". CN values are explicitly defined using hydrologic properties of the soil, land use and cover, and watershed condition prior to rain.

In this study, SCS CNs were determined from rainfall-runoff pairs measured in six forested watersheds. The effects of initial abstraction, antecedent rainfall and terrain slope on runoff response were examined. Various methods were used to estimate CNs for forest land cover using rainfall-runoff events.

Runoff was primarily related to rainfall, but the response varied depending on rainfall intensity, antecedent rainfall and watershed characteristics. The S values have little relationship with antecedent rainfall, but AMC in NEH-4 was not verified by these data. CNs decreased slightly as land slope increased. CN I, II and III were derived according to the 90%, 50%, and 10% exceedance probabilities of the derived S distribution. Resulting values for CN II varied from 75 in deciduous forest to 81 in a mixed forest.

Key words: parameterization; SCS CN method; forest watershed; rainfall-runoff event; AMC

[59]

Methane flux characteristics in temperate forest watershed under Asian monsoon climate

Masayuki Itoh[1], Ayaka Sakabe[2], Mioko Ataka[2], Hiroki Iwata[3], Kenshi Takahashi[4], Yoshiko Kosugi[2], Nobuhito Ohte[5]

[1]Center for Southeast Asian Studies, Kyoto University, Japan
[2]Faculty of Agriculture, Kyoto University, Japan
[3]Faculty of Science, Shinshu University, Japan
[4]Research Institute for Sustainable Humanosphere, Japan
[5]Graduate School of Informatics, Kyoto University, Japan

Abstract:

It is generally thought that forests function as a sink for methane (CH_4) because of the CH_4 oxidation capacity of dry forest soils. However, in forests subject to a humid climate, wetlands often occur in riparian zones. To understand how hydrological processes affect biogeochemical and CH_4 cycles in temperate riparian wetlands, we measured CH_4 fluxes as well as dissolved chemical constituents and CH_4 concentrations in groundwater in wetlands located within a forested catchment in Japan. Strongly reducing conditions and the highest dissolved CH_4 in groundwater was observed during the summer. CH_4 emissions from riparian wetlands were observed almost throughout the year, with clear seasonality. Occasionally in summer, emission rates were more than four orders of magnitude greater than hillslope uptake rates. As for inter-annual variability, CH_4 emissions were constrained in dry and pluvial years, which can shift subsurface soil to a more oxidized condition.

We also measured spatio-temporal variations of CH_4 fluxes in unsaturated forest soils on different parts of a hill slope, in order to determine the effect of precipitation patterns. Soil uptake of CH_4 may possibly be suppressed in regions like Japan with heavy summer precipitation. On the drier parts of the slope, CH_4 uptake was observed throughout the year. In contrast, in the relatively wet, lower part of the slope near the riparian zone, CH_4 emissions were observed during the rainy summer. In this wetter plot, the soil functioned as a net annual CH_4 source during a rainy year. Our results suggest that (1) hydrological processes in forested headwater catchments play an important role in CH_4 formation; (2) small wetlands in forested watersheds function as large sources of CH_4; and (3) consideration of soil water conditions across a forested watershed is important for estimating the CH_4 budget, particularly in regions subject to a wet summer.

Key words: methane; forest catchment; redox condition; Asian monsoon; biogeochemical reactions

[60] Poster

Chemical changes in leachate from forest floor under different acid rain conditions for three subtropical succession forests

Jun Jiang[1,2], Junhua Yan[1]

[1]Key Laboratory of Vegetation Restoration and Management of Degraded Ecosystems, South China Botanical Garden, Chinese Academy of Sciences, Guangzhou 510650, China
[2]University of Chinese Academy of Sciences, Beijing 100049, China

Abstract:

Elevated anthropogenic acid deposition has greatly altered forest ecosystem functions, threatening water resources in subtropical China. The objective of this study was to investigate how forest type and acid rain affect the chemicals in leachate from the forest floor. Three gradients of simulated acid rain treatments (pH4.0, pH3.0, and pH2.0) were designed for 15 soil monoliths (0.2m diameter; 0.4m depth) in Masson pine forest (PF), coniferous and broadleaved mixed forest (MF) and monsoon evergreen broadleaved forest (BF), which represent a subtropical forest succession gradient from pioneer to transition and advanced stage, respectively. PF and MF showed a similar response to acid rain of chemicals in leachate from soil monoliths, with no significant difference in pH, dissolved organic carbon (DOC), SO_4^{2-}, total nitrogen (TN) or cations (K^+, Ca^{2+}, Na^+, Mg^{2+}, Fe^{3+}, Al^{3+}) in leachate from soil monoliths between the pH4.0 and pH3.0 treatments. However, the pH2.0 treatment significantly reduced pH and increased DOC, SO_4^{2-}, TN and cations in leachate for both PF and MF. There were no significant changes in leachate chemistry in BF under the three treatments. Our findings indicated that the forest floor in BF has a higher buffering capacity for acid deposition than that in PF or MF. Therefore, large-scale conversion of pioneer or transition forests to mature forests in subtropical China will increase the capacity of forest ecosystems to buffer acid rain and may have important benefits on water quality and aquatic biological activities in the future.

Key words: forest type; acid rain; chemicals in leachate; forest floor; subtropical China

[61]

Carbon drainage fluxes provide ecohydrological insights across spatial scales in a coastal Pacific watershed

Mark S. Johnson[1,3], Ashlee Jollymore[1], Rachhpal Jassal[2], Lain Hawthorne[3], T. Andrew Black[2]

[1]Univesity of British Columbia (IRES), Canada
[2]Univesity of British Columbia (LFS), Canada
[3]Univesity of British Columbia (EOAS), Canada

Abstract:

Carbon is transported by water from terrestrial to aquatic ecosystems through carbon drainage fluxes. The study of carbon drainage fluxes involves consideration of the downstream transport of carbon, as well as the loss of carbon to the atmosphere via gaseous emissions from the water surface. Improving our understanding of carbon drainage fluxes across spatial scales that link the biosphere, hydrosphere and atmosphere is necessary to discern anthropogenic impacts on the water and carbon cycles, as well as the climate system.

In this presentation, we provide a synthesis of five years of measurements of dissolved organic carbon (DOC) and dissolved CO_2 drainage fluxes for a Pacific coastal Douglas-fir watershed near Campbell River, BC, that underwent clearcut harvesting. We evaluate conditions under which DOC export was supply vs. transport limited, and use fluorescence properties and optical indices to explore DOC quality in relation to DOC flux characteristics. In addition to the utility of carbon drainage flux measurements for improving understanding of the carbon balance of forests, we evaluate the temporal lag between (i) seasonal peaks in ecosystem-scale primary productivity and (ii) dissolved CO_2 at the terrestrial-aquatic interface as a means for characterizing ecohydrological coupling across spatial scales.

Key words: ecohydrology; dissolved organic carbon; dissolved CO_2; DOC quality; terrestrial-aquatic connectivity

[62]

High tech meets low tech: Facilitating citizen science approaches through improvements in water quality analysis

Ashlee J. Jollymore[1], Mark S. Johnson[2], Morgan Haines[3]

[1]Institute for Resources, Environment and Sustainability, University of British Columbia, Canada
[2]Institute for Resources, Environment and Sustainability, Earth Ocean and Atmospheric Studies, University of British Columbia, Canada
[3]University of British Columbia, Canada

Abstract:

Citizen science projects – where the public plays an active role in a research program– combine advocacy and education, with the potential for increasing the public outreach of research projects. The type of project possible can be constrained by resources, economic and otherwise, necessary to determine and manage data. Specifically, water quality analysis can be costly, limiting the potential for citizen involvement. The emergence of new techniques and methods for analyzing water quality that require fewer resources increases the ability to use citizen scientists for environmental monitoring. The relatively recent emergence of low cost, high-throughput techniques for analyzing organic matter allowed us to apply citizen science to survey relationships between forest cover loss and urbanization on surface water quality around the Lower Mainland in British Columbia, Canada. Community members collected over 200 samples from a variety of watersheds exhibiting a gradient of forest cover loss and urbanization; this was done through a simple protocol (including detailed location and site descriptions) using a provided kit. Samples were analyzed for water quality metrics, including organic matter concentration and quality, through absorbance and fluorescence spectrophotometry. The diversity and number of sample sites allowed for the emergence of organic matter fingerprints that stem from land use effects on water quality. While sample diversity was driven by citizen participants, the ability to analyze these community-collected samples was only possible because of the spectrophotometric methods employed. These specific technologies are relatively new, and significantly reduce the time required for analysis, improve our ability to observe subtle changes in organic matter, and reduce cost when compared to traditional analytical approaches, making it possible to survey organic matter through a citizen science approach.

Key words: citizen science; organic matter; forest cover loss; water quality

[63] Poster

Evapotranspiration, surface conductance and water-use efficiency of two young hybrid-poplar plantations in Canada's aspen parkland

Hughie Jones[1], T. Andrew Black[1], Rachhpal S. Jassal[1], Zoran Nesic[1], Jagtar S. Bhatti[2], Derek Sidders[2]

[1]Biometeorology and soil Physics Group, University of British Columbia, Canada
[2]Canada Forest Service, Northern Forestry Center, Edmonton, Canada

Abstract:

The sustainability of fast-growing hybrid poplar (HP) afforestation within the aspen parkland of Canada is questionable, given the low annual precipitation and high potential evaporation during summertime. HP plantations established on former agricultural land have the potential to produce biomass for bio-energy, high-quality fibre and ecosystem services including carbon (C) sequestration. In May 2010 and June 2011, we began using the eddy-covariance (EC) technique to measure water vapor, CO_2 and sensible heat fluxes above two young HP plantations, HP09 and HP11, on Class 1 Chernozemic soil near Edmonton, AB and Winnipeg, MB, respectively. Measurements showed that maximum annual evapotranspiration (E) exceeded 600 mm at HP09 but never exceeded 400 mm at HP11. Water-use efficiency, calculated as gross primary productivity divided by E, was highest at HP11, reaching a maximum of 1.9 g C kg^{-1} H_2O. Half-hourly surface conductance (gs) was estimated using a biophysical model and compared to bulk gs calculated using EC-measured E, climate data and the inverted Penman-Monteith equation. The model is composed of a big-leaf model for estimating transpiration (Ec) complemented with a Priestley-Taylor equation for estimating soil evaporation (Es). Diurnal and seasonal agreement between modelled and measured gs was good at both sites, enabling us to make robust daily and annual estimates of E during leafless and full-leaf periods. The modelled partitioning of E into Ec and Es suggests that Es dominates plantation E during the first 1-2 years of HP development, but as HP plantations mature Ec increases, resulting in increased annual E. In some years, specifically the 3rd and 5th years of growth at HP09, E exceeded precipitation, which stresses the need for further water balance studies and evapotranspiration modelling to evaluate the sustainability of large scale HP afforestation with regards to local and regional water balance.

Key words: evapotranspiration; surface conductance; water balance; modelling; water use efficiency

[64]

Investigating exchange of carbon and water at a subtropical wetland ecosystem close to a metropolitan area

Jehn-Yih Juang[1]

[1]Department of Geography, National Taiwan University, Taiwan

Abstract:

In this study, we quantified the ecosystem-scale CO_2 and water exchange of two different but typical low-latitude vegetation types, para grass and reed, in a subtropical wetland ecosystem close to a metropolitan area by integrating flux observation with the parameterization of environmental variables. In addition, we explored how the seasonal dynamics of environmental factors affected variations in carbon and water budget in the area. The results suggest that gross primary production (GPP, in the order of 1700 g C m^{-2} yr^{-1}) of CO_2 was higher at this wetland than in northern peatlands and estuarial wetlands because of direct effects of environmental factors. Temperature and radiation had more effect on GPP than water status (soil moisture content and vapor pressure deficit) for the two low-latitude ecosystems, which differs from the results for high-latitude regions. Environmental variables had a strong but different impact on the carbon and water budget for para grass and reed areas. This diversity led to different potential shifts and trends of biomass accumulation and distribution under different scenarios of environmental change. The finding from this study provide a quantitative understanding of CO_2 and water budgets in low-latitude wetlands at different temporal and spatial scales.

Key words: eddy covariance; flux; environmental controls; seasonal dynamics

[65]

Generating a provincial assessment procedure for watershed evaluation

Zaid Jumean[1], Richard Thompson[1], Lars Reese-Hansen[2], Peter Tschaplinski[1], Dave McEwan[1], Sasha Lees[2], Marc Porter[3], Simon Casely[3]

[1]BC Ministry of Environment, Canada
[2]BC Ministry of Forests, Lands, and Natural Resource Operations, Canada
[3]ESSA Technologies, Canada

Abstract:

Over the past 3 years, British Columbia has been exploring a framework for assessing the cumulative effects of disturbances on key environmental values, with the ultimate goal of developing a provincially-consistent procedure for value assessment. As part of this work, demonstration projects were identified as "testing labs" to develop methodologies for assessing broad scale cumulative effects on values. One key value that was consistent between demonstration projects was an assessment of watershed condition. In addition to the demonstration projects, other watershed-based assessment initiatives are on-going. The common thread between these watershed-based assessment initiatives was the use of key watershed risk indicators in a GIS-based environment, and an interpretation of watershed condition risk based on the indicator analysis. Though each assessment procedure was developed to address cumulative effects of natural and/or anthropogenic processes on watershed condition, each approach was developed in a slightly different manner. In the current phase of cumulative effects implementation in BC, our primary goal is to identify provincially-consistent methods for assessing impacts to key values. In this talk, I will present the process that our technical working group employed to generate a provincial assessment procedure for assessing risk to watershed condition. I will describe how we considered varying watershed assessment initiatives, discuss the value and challenges of bringing various groups and individuals together for the development of a provincial procedure, review the outcomes of our work, and provide recommendations for similar exercises that may be undertaken in the future.

Key words: cumulative effects; provincial consistency; watershed risk; collaboration

[66]

How hazardous is the lack of forest road maintenance to fish habitat in Quebec's public forested lands?

Sylvain Jutras[1]

[1]Département des sciences du bois et de la forêt, Faculté de foresterie, de géographie et de géomatique, 2405, rue de la Terrasse, Pavillon Abitibi-Price, local 2150, Université Laval, Canada

Abstract:

Stream waters in Quebec's boreal shield generally have low temperatures and low nutrient concentrations. When best management practices are used (soil protection, buffer strips, etc.), forest harvesting has had limited and short duration effects on water quality. The most detrimental modification of water properties comes from the input of sediments to streams. While numerous land users are claiming that abandoned roads and water crossings might be responsible of frequent bursts of sediments, very little data is available either to support or deny this statement.

Since 1987, the construction of roads and water crossings on Quebec's public forested lands must follow very precise regulations. However, there is a total absence of rules concerning the mid- to long-term maintenance of this infrastructure. The owner of all these road structures, the provincial ministry of forests, manages a forest roads database, but it contains only road position and a list of bridges under frequent inspections. It is incomplete because it does not contain information on the conditions of surfaces, ditches, or culverts. Moreover, 51% of the 330 000 km of gravel roads in the database are described as "unclassified" because of the lack of information. It is possible that a large part of these roads may be completely abandoned, without any decommissioning or proper closing procedure.

Road maintenance investment has been limited. The effect of this lack of upkeep on erosion, sedimentation and fish passage is unknown. Culverts can be washed out at any moment due to lack of maintenance, and no one would know. Determining road maintenance status throughout Quebec's public lands, and understanding its effect on the aquatic environment, is necessary to ascertain the magnitude of the problem. The results of an exploratory study with these objectives will be presented.

Key words: water crossings; culverts; sedimentation; integrated road management; erosion

[67] Poster
Influence of intensive thinning on water and sediment discharge in Japanese coniferous forest plantations

Hiroaki Kato[1], Yuichi Onda[1], Akiko Hirata[1], Soo Youn Nam[2], Takashi Gomi[2]

[1]University of Tsukuba, Japan
[2]Tokyo University of Agriculture and Technology, Japan

Abstract:

Approximately 40% of the Japanese land area consists of coniferous forest plantations. Most of those plantations have been unmanaged for a long period of time due to stagnant wood prices and resulting decline of the forest industry. The unmanaged plantations are characterized by a dense closed canopy and bare soil surface, causing enhanced overland flow generation and surface erosion. In this study, we explored the effects of intensive thinning on water and sediment discharge in abandoned coniferous plantations at the hillslope and watershed scale. We selected experimental watersheds in Tochigi, Aichi, Mie, and Fukuoka Prefectures. A large hillslope erosion plot (40 m^2) was established in each watershed and more than 6 trees were included within each plot. Half of the trees within the watershed were felled in order to measure the changes of water and sediment discharge at hillslope and watershed scales before and after the thinning. Suspended sediment in stream water was collected using an integrated suspended sediment sampler. In order to analyze suspended sediment sources in the experimental watershed, radiocesium concentrations in sediment samples and potential sediment source materials were analyzed and compared. We will present monitoring results of radiocesium discharge in suspended sediment from forested watersheds following the Fukushima Dai-ichi Nuclear Power Plant accident.

Key words: Japanese coniferous plantation; intensive thinning; sediment discharge; radiocesium; Fukushima Dai-ichi Nuclear Power Plant accident

[68]

Hydrological control of perpetual effects of forest disturbance on streamwater chemistry in a forested catchment

M. Katsuyama[1], K. Iwasaki[2], R. Nagano[3], K. Takaki[3], Y. Tanaka[3]

[1]Center for the Promotion of Interdisciplinary Education and Research, Kyoto University, Japan
[2]Forestry Research Institute, Hokkaido Research Organization, Japan
[3] Graduate School of Agriculture, Kyoto University, Japan

Abstract:

We have been monitoring the chemistry of precipitation, ground- and stream water in the Kiryu Experimental Watershed (KEW; 5.99 ha), Japan, and four subcatchments within KEW for more than 20 years.

Streamwater NO_3^- concentrations during baseflow condition is different between the subcatchments, although the current vegetation and geological conditions are similar. The differences are due to the diversity of the hydrological pathways and redox conditions within the soil sediments of each catchment.

One of the subcatchments experienced a disturbance caused by pine-wilt disease in early 1990's, after which time there was an increase in NO_3^- concentration in ground- and streamwater. The concentration in streamwater peaked around 1998 and then decreased; however, it is still higher than the levels measured before the disturbance. The effects of the disturbance are expected to persist for a long time because of contributions from pathways with very long residence times (>10 years), as well as the gradual decomposition of litter.

NO_3^- concentrations have been increasing over the last 5 years in all subcatchments. This trend can explained in one subcatchment by increased disturbance due to bank erosion, but the remaining subcatchments are undisturbed. These recent observations suggest that the 50-year-old, unmanaged artificial forests in KEW may have started degrading, and that the biogeochemical cycle may start changing.

Because the life cycle of forests occurs over decades and centuries, ecosystem-scale phenomena can only be revealed by long-term observations, and long-term streamwater chemistry dynamics provide a good ecosystem function diagnosis tool. Therefore, it is important to continue water chemistry monitoring at KEW, in order to understand the persistence of forest disturbance effects on hydrology and to improve our models.

Key words: long-term observation; streamwater chemistry; hydrological pathways; residence time; forest disturbance

[69]

The impact of capping thickness on water use of juvenile aspen and white spruce trees: A study on a reclaimed site at the South Bison Hills reclamation area in northern Alberta

Jeff W.G. Kelly[1], Simon M. Landhausser[1]

[1]University of Alberta, Edmonton, Canada

Abstract:

There are numerous unresolved issues facing land reclamation practitioners in the boreal forest region of northern Alberta. Of particular importance is developing a greater understanding of the relationship between soil water availability and forest productivity on reclaimed boreal forest lands. The need for this information, in particular, arises through the common observation that potential evapotranspiration (plant transpiration plus soil evaporation) often exceeds precipitation in many parts of the boreal forest zone. For reclamation sites, these patterns in water use are often further amplified by factors such as stage of forest development, droughts, invasive species and alterations to the soil substrate. Therefore, gaining a greater understanding on the hydrology of newly developing forests is essential in order to advise land reclamation practitioners on appropriate capping depths, species selection and monitoring protocols of forest vegetation on reclaimed sites.

In this project, we measured sap flow for the two dominant tree species (aspen and white spruce) found at a soil capping trial in northern Alberta. Our key questions throughout the project centre on the effect of capping thickness and slope position on tree and forest water use. Assessment of soil water availability and tree water use is an integral means to determine forest development and forest trajectories. Not only is this information important to those involved in land reclamation, it may also provide greater ecological insight into patterns of forest establishment and maintenance following large scale disturbances (both natural and human caused). Such information on water use and forest trajectories is useful in both an applied sense (i.e., development of management plans, monitoring and risk assessment) and in providing baseline information for use in modeling of these forests to better assess the risk of low soil water availability on reclaimed forests both across the landscape and over time.

Key words: reclamation; sap flow; soil water availability; leaf area; rooting depth

[70]

The effects of thinning intensities on transpiration and productivity of 50-year-old *Pinus koraiensis* stands

Hyun Seok Kim[1,2,3,4], Juhan Park[1], Sungsik Cho[1], Daun Ryu[1], Minji Park[1], Khine Zaw Wynn[1], Boknam Lee[1], Minkyu Moon[3], Taekyu Kim[5]

[1]Department of Forest Sciences, Seoul National University, Seoul, Rep. of Korea
[2]National Center for AgroMeteorology, Seoul, Rep. of Korea
[3] Research Institute for Agriculture and Life Sciences, Seoul National Univeristy, Seoul, Rep. of Korea
[4]Interdisciplinary Program in Agricultural and Forest Meteorology, Seoul National University, Seoul, Rep. of Korea
[5]National Institute of Environmental Research, Incheon, Rep. of Korea

Abstract:

Forests play a significant role in the water and carbon balance of ecosystems by absorbing atmospheric CO_2 and storing carbon in biomass, while they lose water through transpiration. Forest management practices such as thinning can change the carbon uptake capacity of forests, although these effects are hard to evaluate. For more precise evaluation of the initial effects of thinning intensities on individual tree and stand water and carbon balances, transpiration and productivity of a 50-year-old *Pinus koraiensis* plantation was monitored for a year after 20% and 40% thinning. At the tree level, there was a significant increase of transpiration at the thinned plots, with the largest differences during the summer. However, there was no significant difference between 20% and 40% thinned plots. In contrast, stand transpiration was 9~40 % higher at the control plots than at the thinned plots, due to larger sapwood and leaf area. Similar to water use, the diameter growths of individual trees were 59% and 34% in the thinned plots, compared to 40% and 20% at the control plots. This increase of individual tree growth by thinning resulted in an increase in stand net primary productivity (NPP), even though stand density was reduced by thinning. Thinning reduced stand transpiration without decreasing stand NPP due to improved light condition and reduced competition, which increased water use efficiency. This tendency was significant in heavily thinned plots, where water use efficiency (2.13 ± 0.15 g C kg^{-1} H2O) was 43% higher than at control plots (1.49 ± 0.65 g C kg^{-1} H2O). Our study showed that different intensities of thinning treatment resulted in a change in water use at individual tree and stand levels. Changes in water use resulted in a change in productivity and WUE of a Korean pine plantation.

Key words: transpiration; productivity; thinning intensity; water use efficiency; *Pinus koraiensis*

[71]

Variation in carbon and nitrogen inputs and pools along an elevation, precipitation and vegetation gradient in southern Appalachian forests

J.D. Knoepp[1], J.M. Vose[2], J.S. Clark[3], C.F. Miniat[1]

[1]USDA Forest Service, Southern Research Station, Center for Forest Watershed Science, Coweeta Hydrologic Laboratory, U.S.A.
[2]USDA Forest Service, Southern Research Station, Center for Integrated Forest Science and Synthesis, NC State University, U.S.A.
[3]Nicholas School of the Environment, Department of Statistical Science, U.S.A.

Abstract:

The role of forests in C sequestration is of global interest and, while recent progress in characterizing terrestrial C pools and fluxes at global scales has been made, challenges remain in characterizing how C pools and fluxes vary in time and space, particularly in landscapes with high variability in precipitation and temperature, vegetation diversity, and topography, such as southern Appalachian mountain forests.

In 1990, as part of the Coweeta Long-term Ecological Research (LTER) program, we established five large permanent plots across an elevation, precipitation, and vegetation gradient in the southern Appalachian forests within Coweeta Hydrologic Laboratory, a US Forest Service Experimental Forest, in western North Carolina, USA. The gradient forest communities include mixed oak-pine, mixed oak, cove hardwood and northern hardwoods; elevation ranges from 790 to 1390 m. Annual precipitation ranges 210 to 268 cm, and air temperature ranges 15.1 to 11.8 °C along the gradient. We analyzed a 20-yr record of: soil C and N; aboveground species composition, growth, biomass, and C stocks; coarse wood stocks; leaf litterfall and fine wood C flux; and changes over time in soil moisture and vegetation community. We expect to show that (a) total C and N pool sizes are characteristic of vegetation, soil moisture availability and temperature regimes, and (b) deep soil profiles impart a buffering effect, minimizing the sensitivity of soil C and N pools and accumulation rates to variability in soil moisture and temperature as compared to the inter-annual variability of aboveground C pools.

Key words: soil carbon; soil nitrogen; coarse wood; aboveground biomass; net primary productivity; climate variability

[72] Poster
Climate change effects on hydrologic processes in northern forests

Randy Kolka[1], Steve Sebestyen[1], John Campbell[1], Lindsey Rustad[1], Salli Dymond[2], Mark Green[3]

[1]USDA Forest Service Northern Research Station, U.S.A.
[2]University of Minnesota, U.S.A.
[3]Plymouth State University, U.S.A.

Abstract:

Across northern forests in the central and eastern US and southeastern Canada, landscapes range from high elevation, mountainous systems in the east where streams are driven by mainly upland runoff, to relatively low-relief systems in the Midwest where streams are the result of both upland and wetland runoff. Across this gradient, climate change is expected to affect hydrologic processes differently. Two sites span the geographic and geomorphic range of this region: the Hubbard Brook Experimental Forest (HBEF) in New Hampshire, and the Marcell Experimental Forest (MEF) in Minnesota. Each site has hydrologic and meteorological records for the past 50 years. We compared and contrasted how climate change has affected changes in hydrologic processes such as precipitation, streamflow, evapotranspiration, soil moisture and snow melt timing, as well as the overall water budget at the HBEF and the MEF. Initial analyses on the HBEF show increases in precipitation, soil moisture, and streamflow, with no changes or small decreases in evapotranspiration. At MEF, there were no significant changes in long-term annual precipitation, and streamflow has increased in spring but decreased in summer. There are declining trends in soil moisture at MEF. Also, the date of snow melt is tending to be earlier over time. Metrics to assess changes in streamflow variability (i.e. extreme events) will also be presented. Based on our current projections and predictions of future climate, we speculate on the future hydrology of HBEF and MEF and the possible ramifications.

Key words: precipitation; soil moisture; evapotranspiration; snowmelt; streamflow

[73]

The role of the litter layer on the hydrological response of a forested catchment

Koichiro Kuraji[1], Mie Gomyo[1]

[1]Ecohydrology Research Institute, The University of Tokyo Forests, Graduate School of Agricultural and Life Sciences, The University of Tokyo, 11-44 Goizuka, Seto, Aichi 489-0031, Japan

Abstract:

The litter layer on a forest floor can influence both short-term runoff and the long-term water balance through hydrological processes such as litter interception, suppression of ground surface evaporation, mitigation of raindrop energy, increases in permeability, reductions in overland flow, and the creation of a rapid-flow component within the litter layer. The objective of this study is to clarify the effect of litter layers on short-term runoff and the water balance by use of a paired watershed method. Using this technique, we selected two watersheds for our research. In one catchment with an area of 1.19 ha, the experimental removal of a litter layer was conducted once a year over the latter half of a 6-year experimental period. An adjacent catchment with a surface area of 1.42 ha was left undisturbed for use as a reference site. The results indicated that the increase in the annual water loss, estimated by the litter removal experiment, in the three consecutive years of study were 58.8, 18.4, and 8.8 mm, respectively. Additionally, that larger increase in the annual water loss in the experiment correlated positively with greater annual water loss in the reference catchment. Further, the peak runoff during a large flood event increased by a factor of about 1.4, and the time of peak runoff occurrence was about 5.6 min earlier, on average, than that observed before litter layer removal. In addition, the volume of direct runoff during a large flood event increased by about 10%.

Key words: direct runoff; litter layer; paired catchment method; peak runoff; water balance

[74] Poster
Optimization of nickel ion removal from aqueous solutions by chitosan-polyethylene oxide electrospun nanofibers

Ichrak Lakhdhar[1], Patrice Mangin[1], Bruno Chabot[1]

[1]Centre de recherche sur les matériaux lignocellulosiques, Université du Québec à Trois-Rivières, 3351 boul. des Forges, C.P. 500, Trois-Rivières, Quebec, Canada,

Abstract:

Water sustainability is becoming a major concern for Canadians. Various water initiatives are being studied by both provincial and federal governments to recommend water governance and policies that will ensure the sustainability of water supplies for people and industry. The implementation of such water initiatives will have a considerable impact on the pulp and paper industry, which is a major user of water for their operations. To help reduce fresh water usage and effluent loads of paper mills, advanced wastewater treatment will become mandatory to meet targeted fresh water quality goals with minimum detrimental effects on papermaking operations and paper quality. In this study, we propose a new effluent treatment method based on adsorption using electrospun nanofibers produced from partial deacetylation of chitin, producing chitosan. Electrospun chitosan (CS)/polyethylene oxide (PEO) nanofibre mats were prepared to study their potential at removing nickel ions from aqueous solutions, and to investigate the adsorption process of these ions. The effects of contact time, temperature, nickel concentration, adsorbent dose and solution conductivity were determined from batch adsorption experiments. Optimization of nickel removal using a central composite design (CCD) was also carried out to determine the quadratic and combined effects of the main contributing parameters. Results showed that more than 30% of nickel ions were removed from aqueous solutions using 25mg of CS/PEO nanofibers. Optimum adsorption capacity was reached when: initial pH=5.5; nickel concentration=100 ppm; adsorbent dose=75 mg; temperature=75°C; and NaCl concentration=1M. At these optimum conditions, 64% of nickel ions were adsorbed after a contact time of 4h30min. From experimental data, a second-order polynomial equation was developed to describe the relationship between nickel adsorption and operating parameters.

Key words: water sustainability; pulp and paper mills; water recycling; chitosan electrospun nanofibers; nickel adsorption optimization; experimental design

[75] Poster

Spatial and temporal analysis of rainfall variability over Korea

Eun Jai Lee[1], Dong Ik Jung[1], Sangjun Im[1]

[1]Department of Forest Sciences, Seoul National University, Seoul, Korea

Abstract:

Global and local scale rainfall patterns are shifting due to climate change. However, we still lack a clear understanding of these changes, because of natural variability in rainfall itself. Thus, scientific approaches should be introduced to explore climate change signals from a series of rainfall data. We analyzed the long-term trends of rainfall variability over Korea, and characterized the distribution and concentration patterns of rainfall.

The long-term rainfall data-set provided by the Korea Meteorological Administration (KMA) was used to analyze spatial and temporal variability throughout the country. Rainfall amount, number of rainy days, and heavy rainfall intensity were examined first to understand rainfall characteristics among the stations. Rainfall variability descriptors, such as the Precipitation Concentration Index (PCI, Oliver 1980), Fournier Index (FI, Fournier 1960), and Modified Fournier Index (MFI, Arnoldus 1980), were employed to detect the spatial trends in amount and intensity of observed rainfall. Temporal changes in rainfall were also analyzed to compare rainfall amount and intensity among locations and years.

A slight increase in annual rainfall with high variability has been detected in almost all weather stations in Korea. Annual rainfall in flooding years has fluctuated with larger range since the 1990s, while drought rainfall remains nearly constant. All variability indices indicated higher concentrations of monthly rainfall.

A high frequency of intense rainfall, beyond the weather records, has repeatedly occurred over the last decade in Korea. Spatial and temporal changes in heavy summer rainfall can cause natural disasters in rural and urban regions (flooding and landslides), and caused human and financial losses. Therefore, the results of this study are valuable for policy makers to implement disaster mitigation activities, even though past trends of rainfall are not always indicative of future tendencies.

Key words: spatial variability; temporal variation; precipitation concentration index; Fournier index; rainfall variability

[76]

Attribution of decreasing discharge in a typical watershed of the middle Yellow River using a distributed ecohydrological model

Huimin Lei[1], Yang Jiao[1], Dawen Yang[1]

[1]State Key Laboratory of Hydroscience and Engineering, Department of Hydraulic Engineering, Tsinghua University, Beijing, 100084, China

Abstract:

In the past five decades, a significant decrease in channel discharge has been detected in the middle reach of the Yellow River Basin, which has intensified the water resources crisis in this region. This phenomenon is generally considered to be caused by changes in climate forcing, land use and vegetation growth, which are determined by climate variability and local human activities. Many studies of attribution analysis have been carried out on this issue, but most treat vegetation as a static condition prescribed by known information without considering vegetation dynamics. In fact, a significant increase in vegetation greenness has already been observed in this region, hypothesised to be a response to significant increases in air temperature and the implementation of large-scale afforestation. In this study, a new processes-based distributed ecohydrological model, which couples energy balance, water balance, dynamic vegetation phenology, and river routing, has been developed to consider the interactions between climate and vegetation. Based on the newly developed model, this study attempts to explain the increase in vegetation and diagnose reasons for the decline in river discharge.

Driven by observation data from 12 meteorological stations, 91 rain gauges, one flux tower, and several remote-sensing products, the model is validated at both single-point and catchment scales, and then applied at a spatial resolution of 0.01 degree (about 1km) in Wudinghe River Basin located in the Middle Yellow River (drainage area 28,706 km^2). After model spin up under climate conditions for 1960-1979, several simulations with different configurations have been designed. By comparing simulation results, the effects of climate variability, afforestation and natural vegetation dynamics can be distinguished. This study contributes to our understanding of the decrease in discharge.

Key words: river discharge; vegetation dynamics; attribution analysis; ecohydrological model; Yellow River Basin

[77] Poster

Development of a strategic level GIS indicator-based watershed assessment procedure for assessing cumulative hydrologic effects

Doug Lewis[1], Michael Milne[2], Bill Grainger[3]

[1]BC Ministry of Forests, Lands and Natural Resource Operations, Kamloops, BC, Canada
[2]M.J. Mile & Associates Ltd., Vernon, BC, Canada
[3]Grainger & Associates Ltd., Salmon Arm, BC, Canada

Abstract:

We present a GIS indicator-based watershed assessment procedure applicable to strategic-level (sub-regional to regional) assessment of snowmelt-dominated watersheds in the southern interior of British Columbia. The procedure builds from existing assessment approaches developed in BC, responding to the need to understand potential cumulative hydrologic effects, through time and over large areas, resulting from multiple land use activities and large scale natural disturbances. At the strategic-level, the procedure is intended to act as a screening tool, to flag higher risk watersheds for further investigation by qualified professionals as part of a multi-step approach. We stress that GIS-based indicators alone should not be misused as management limits.

The procedure uses a risk-based approach, where risk is the product of hazard and consequence. The procedure provides hazard ratings as an expression of the likelihood of hazard occurrence for key hydrologic processes related to streamflow, sediment generation and delivery, and riparian function. The hazard ratings are intended to be used with consequence ratings derived for downstream ecological (e.g. fish, water quality) and socio-economic values (e.g. human life, property, infrastructure) to derive risk ratings. Hazard ratings are derived by combining indicators that reflect hydrologic and geomorphic characteristics of multiple watersheds (site factors), with indicators related to the type, extent and severity of natural disturbances, land use and industrial activity (development factors).

We recognize this approach relies strongly on GIS indicators and may lack the certainty of data-driven empirical models or site-level field assessments. Nevertheless, we have a high level of confidence that the indicators, and their application in this method, give a useful first approximation at a strategic level of watershed characteristics affecting streamflow, sediment dynamics and riparian function. We strongly recommend that further work is required to validate model outcomes, and adjust indicators and hazard ratings accordingly.

Key words: watershed assessment; strategic-level; cumulative hydrologic effects; risk ratings; hazard ratings

[78]

The application of a strategic-level watershed assessment procedure towards managing the unintended consequences of cumulative hydrologic effects in the southern interior of BC

Doug Lewis[1], Eric Valdal[1], Michael Milne[2], Bill Grainger[3], Rich McCleary[1]

[1]BC Ministry of Forests, Lands and Natural Resource Operations, Kamloops, BC, Canada
[2]M.J. Mile & Associates Ltd., Vernon, BC, Canada
[3]Grainger & Associates Ltd., Salmon Arm, BC, Canada

Abstract:

In British Columbia, managing the unintended consequences to downstream watershed values due to combined effects of multiple land uses and natural disturbances (aka 'cumulative hydrologic effects') on public lands is an emerging and complex issue. In individual watersheds, cumulative hydrologic effects may emerge where multiple, overlapping tenure-holders complete assessments and make project-level decisions in isolation of the effects of other tenure-holder activities, land uses (e.g. private land) or natural disturbances. In multiple watersheds at a sub-regional to regional scale, the potential for cumulative hydrologic effects increases when numerous project-level decisions are driven by broad-scale management responses (e.g. MPB salvage) or development trends (e.g. wind power or pipeline development).

The challenge in assessing cumulative hydrologic effects at strategic levels lies in disentangling the relative effects and interactions between background hydrologic and geomorphic characteristics of multiple watersheds that vary considerably at a regional scale, with a multitude of natural disturbances, land uses and industrial activities that also vary in extent and intensity at this scale. However, if these assessments are effective, results can help inform management decisions and direct regulatory and policy changes to mitigate unintended outcomes.

We demonstrate the application of strategic-level cumulative effects assessment (SCEA), utilizing a GIS indicator-based watershed assessment procedure validated with field-based measurements, as a useful tool to inform management of cumulative hydrologic effects. SCEA can be used to emphasize watersheds of concern based on watershed characteristics, development trends and downstream values at risk within a broader geographic or temporal context. Although SCEA results are provided at a resolution too coarse to direct on-the-ground mitigations, it is useful to prioritize areas for more intensive field-based investigations and to accentuate policy or regulatory gaps necessary to enable coordinated watershed assessment and management planning.

Key words: cumulative hydrologic effects; cumulative effects assessment; unintended consequences; watershed assessment

[79] Poster

A global review on the effects of land cover and climate changes on water resources at large watersheds: Implications for management

Qiang Li, Adam Wei

Department of Earth and Environmental Sciences, University of British Columbia Okanagan, Canada

Abstract:

Water availability is of the utmost importance for now and future development and environmental protection. In spite of various factors, climate variability and vegetation cover change are commonly believed to be two major drivers in influencing water resources. This study reviewed published studies from 160 large watersheds (>500 km^2) from around the world. Based on the Budyko Curve, E_0/P (potential evapotranspiration/precipitation) was selected as the indicator for climate variability, while watershed area and vegetation cover change represented watershed properties. Our meta-data analysis shows that the impacts of land cover change on water can be as important as the influence of climate change. In addition, hydrological sensitivity increases with E_0/P (dryness index), which is different from the commonly held perception (i.e., the sensitivity at $E_0/P = 1$ is the highest). Large watersheds have the ability to buffer the effects of land cover change on water yield. The implications of our results for watershed management are discussed in the context of future climate and land cover changes.

Key words:

[80]

Rainfall interception by canopy and leaf litter in northern China: A joint measurement

Xiang Li[1], Qingfu Xiao[2], Jianzhi Niu [1], Xinxiao Yu [1], Baoyuan Xie [1]

[1]Key Laboratory of Soil and Water Conservation and Desertification Combating of Education Ministry, Beijing Forestry University, Beijing, China.
[2] Department of Land, Air and Water Resources, University of California, Davis, U.S.A.

Abstract:

Rainfall interception has been one of the most underrated hydrological processes in forest ecosystems. However, several studies have shown that although interception is probably a minor process statistically, its role as a rainfall redistributor affected not only evaporation and transpiration processes but also the water balance, water resources management and climate change impacts. Previous studies focussed mainly on either canopy interception or forest floor interception, and joint measurements of the two interception processes was seldom reported. On the other hand, canopy and leaf litter interception apparently interact when rainfall occurs, the need for joint interception measurement requires further research. An experiment with a new approach was conducted to measure canopy and leaf litter interception together for four broad- and needle-leaf tree species (2 trees for each species) under five simulated rainfall intensities, in order to quantify rainfall-interception relationships and comprehensively illustrate joint interception mechanisms. Results indicated that the maximum joint interception storage capacity (Imax) by canopy and leaf litter (taken as the amount of rainwater immediately detained in the sample before rainfall cessation) was 16.6 % of the precipitation, while the minimum (Imin) (the amount of rainwater in the sample after drainage had ceased) was only 4.3 % of the precipitation regardless of tree species and rainfall intensity. Compared to the canopy interception alone, joint Imax and Imin surprisingly increased by 15.2 and 3.3 % respectively. Joint Imax and Imin of broad-leaf canopy and litter were 1.53 and 1.68 times larger than those of needle-leaf canopies, respectively. No linear relationships were detected between rainfall intensity and Imax or Imin, but both increased with increasing litter mass. We conclude that joint interception by canopy and leaf litter must be taken into account in future studies, especially in hydrological models.

Key words: rainfall interception; hydrological processes; joint measurement; canopy interception; leaf litter interception

[81]

Atmospheric nutrient input and how it is influenced by forest succession stage in south China

Yuelin Li[1], Guoyi Zhou[1], Deqiang Zhang[1], Shizhong Liu[1], Qianmei Zhang[1], Guowei Chu[1]

[1]South China Botanical Garden, Chinese Academy of Sciences, Guangzhou 510650, PR China

Abstract:

Incident rainfall, together with associated throughfall and stemflow, is a major source of nutrients to forest ecosystems. Dinghushan Nature Reserve in south China is characterized by three distinct forest types representing typical subtropical forests at different succession stages from pioneer to near climax forest communities: pine forest, mixed pine broadleaved forest and monsoon broadleaved evergreen forest. We investigated atmospheric inputs of five nutrient elements (K, Ca, Mg, N and P) in these three forest types. We determined the concentrations of these nutrient compounds in bulk precipitation, throughfall and stemflow. Concentrations of the measured nutrients were ranked as rainfall < throughfall < stemflow. In all three forests, Ca concentration in throughfall was lower than in rainfall. Nutrient concentrations in throughfall and stemflow didn't show any significant difference among forests, but nutrient inputs in stemflow had an increasing trend with the progress of succession, especially in the mixed and pine forests. Results indicated that rainfall not only played an important role in nutrient transfer from forest canopy to soil, but also supplied necessary nutrients for forest growth, especially at an early successional stage. Our research contributes to the analysis of nutrient input fluxes via bulk precipitation, throughfall and stemflow, providing a better understanding of the biogeochemical functioning of tropical forests in southern China that are influenced by atmospheric inputs under the monsoon climate change.

Key words: atmospheric input; rainfall redistribution; throughfall; stemflow; Dinghushan

[82]

Spatial and temporal variations in the surface and subsurface water in a natural forested headwater catchment

Wei-Li Liang[1], Sheng-Lun Li[1], Meng-Chun Chan[1]

[1]School of Forestry and Resource Conservation, National Taiwan University, Taipei, Taiwan.

Abstract:

Surface or subsurface soil moisture at the interface between atmospheric and terrestrial environments has significant implications for the complex interactions between hydrological processes and ecosystems. Particularly, surface–subsurface water interactions could be more complex in a natural forested headwater catchment, where hydrological and erosional responses are active. In this study, we measured detailed surface soil water content at 470 points using TDR (time domain reflectometry), and monitored pore water pressure at the soil–bedrock interface at 60 points using tensiometers in a natural forested headwater catchment. Observations showed that the spatial patterns of surface soil moisture differed between locations, which could be approximately classified into three topographic units within the site: two gullies, the valley-head hillslope, and the side hillslope. The two gullies always had relatively high soil water content, while the side hillslope always had relatively low soil water content. In terms of subsurface water movement, the subsurface saturated area of the valley head site extended from the bottom to the upper portion of the hillslope when the amount of rainfall increased, whereas the movement of subsurface saturated water was much more variable at the middle hillslope during storm events. Subsurface saturation was generated fragmentarily and locally at first, and then connected to flow downslope, flowing from the upper or middle slope areas to the lower slope area. Thus, both ‘‘upper–lower’’ and ‘‘fragment–integration’’ processes occurred during saturated zone expansion at the soil–bedrock interface.

Key words: headwater catchment; saturated zone; soil–bedrock interface; surface moisture; topographic unit

[83] Poster
Fine root biomass of Chinese fir and their responses to environmental factors in subtropical China

Yingchun Liao[1,2], Houbao Fan[1], Huimin Wang[*2]

[1]Institute of Ecology & Environmental Science, Nanchang Institute of Technology, Nanchang 330099, China
[2]Qianyanzhou Ecological Research Station, Key Laboratory of Ecosystem Network Observation and Modeling, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China

Abstract:

The biomass, functional traits and morphological characteristics of fine roots vary with different environmental factors. Understanding of the patterns of fine root distribution of Chinese fir and their relationships with soil C and aboveground biomass can help to predict the contribution of fine root turnover to soil C accumulation and C allocation to aboveground plant parts.

A study was conducted in 6 subtropical Chinese fir (*Cunninghamia lanceolata*) plantations in different areas to assess the fine root mass density (FRMD) of different fine roots groups (1,2 order roots, 3-5 order roots and herb-shrub roots) as well as their relations with soil C and aboveground biomass.

FRMD was closely related to soil C concentration but varied with soil layer and between study areas. The FRMD of gross roots (which included absorptive roots, 3-5 order roots and herb-shrub roots) was positively related to soil C concentration ($P < 0.05$) in areas with high FRMD, while there were no significant correlations between FRMD and soil C concentrations in the areas with low FRMD. The ratio of aboveground biomass production (mean annual aboveground biomass increase per tree) to absorptive root biomass could be used to characterize the contribution of absorptive roots to aboveground biomass. The ratios of aboveground biomass production to absorptive root biomass of Chinese fir were much higher in central areas than in outer areas of subtropical China.

Soil C was mainly affected by herb-shrub roots in upper soil layers and by Chinese fir roots in deeper soil layers. The allocation of tree biomass to aboveground biomass were higher in central areas than in outer areas in subtropical China.

Key words: fine roots; soil C; fine root mass density (FRMD); absorptive roots; fine root traits

[84]

Trends of runoff–sediment behavior in flood events under vegetation restoration in a catchment on the Loess Plateau, China

Pengfei Lin[1,2], Xiaoping Zhang[1], Abla Muratjan[3], Lili Chen [3], Wenhui Zhao[3], Jianjun Zhang[1,2], Rui Yan

[1]State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau, Institute of Soil and Water Conservation, Chinese Academy of Sciences and Ministry of Water Resources, Yangling, Shaanxi, 712100, China
[2]University of Chinese Academy of Sciences, Beijing, 100049, China
[3]Resource and Environment College, Northwest A & F University, Yangling, Shaanxi, 712100, China

Abstract:

The Loess Plateau has experienced large scale land use/cover changes since the implementation of extensive soil conservation measures in the 1970s and the "Grain for Green" project implemented in 1999. Annual runoff and sediment load have significantly decreased, and annual and seasonal runoff-sediment relationships changed remarkably. However, how runoff-sediment behavior during flood events changes in this area is not fully understood. A total of 358 flood events from 1963 to 2011 were investigated in the Wuqi catchment, located in the upper reaches of the Beiluo River. Results showed that annual average runoff depth and sediment load for all the flood events were 12.4 mm and 9080.6 t/km^2, which accounted for 45.6% of annual average total runoff volume and 90.49% of annual average total sediment yield, respectively. With land use and cover changes, the occurrence of flood events decreased from an average of 10 times per year in 1963-1979, to 7 times per year in 1980-2002, and to only 4 times per year in 2003-2011. At the same time, the average annual runoff depth for the flood events decreased significantly from 17.6 mm (54.1% average annual total runoff) to 12.3 mm (436%) and to 2.9 mm (18.7%) for 1963-79, 1980-2002 and 2003-2011, respectively. The average sediment load for flood events also decreased from 13694.1 t km^{-2} y^{-1} to 8642.7 t km^{-2} y^{-1} and to 1485.1 t km^{-2} y^{-1}, but remained up to 90% of total sediment yield. The shape of counterclockwise loop dominated flood events, while the frequency of clockwise loop events increased. The linear regression for runoff and sediment yield for flood events with 1 to 2 year return periods showed a significant decreasing trend in the sediment production coefficient. However, flood events with a greater than 5 year return period did not demonstrate any change in the sediment production coefficient. Results showed that vegetation restoration caused the decrease in runoff generation and sediment yield during flood events, but it did not alter runoff-sediment behavior, especially during extreme events in this area.

Key words: runoff–sediment behavior; flood events; soil and water conservation; ecological restoration; Loess Plateau

[85]

Vegetation dynamics and rainfall sensitivity of the Australia continent

Ning Liu[1], Richard Harper[1], Bernard Dell[1], Shirong Liu[2]

1School of Veterinary and Life Sciences, Murdoch University, Australia
2Chinese Academy of Forestry, China

Abstract:

Over the past 100 years, Australia has experienced pronounced climate change in terms of rising temperatures and significant changes of rainfall patterns. The decline of rainfall has resulted in a >50% decrease of runoff in the southwest since 1975, and similar patterns have been seen in other regions. Severe droughts have caused large areas of forest mortality in the past decades. This paper examines vegetation dynamics and their sensitivity to rainfall change in the Australian continent over the last decade, using a vegetation index derived from MODIS and gridded climate and hydrological data from Terrestrial Ecosystem Research Network (TERN). We found that rainfall declined across 68% of the continent and across about 50% of the forest area since 2000. The net change of rainfall was between -38 mm/month and 57 mm/month with a mean of -2.4 mm/month. The normalized difference vegetation index (NDVI) increased across 62% of the continent, with a range of -0.2 to 0.3, and increased across 96% of the forest area. The most dramatic decline in NDVI was observed in the scrublands area at the centre of the Australian continent, which coincided with significant reductions in rainfall, runoff and terrestrial water storage (TWC) (from the Global Land Data Assimilation System (GLDAS)). For forested areas, there was no significant decline of TWC and no strong relationships between the change of rainfall, runoff and NDVI. Our results provide evidence that, at this scale of assessment and with these interpolated data sets, the current decline of rainfall has not been the key factor causing changes of vegetation growth in forests. These relationships have been found in studies undertaken at a finer scale. However, several model results indicate that rainfall will decline further in some regions by the end of the 21st Century, which means that the water deficit will increase further. Therefore, it is urgent to understand what the likely effects of soil water will be on vegetation with these future changes.

Key words: Australia; climate change; precipitation; NDVI; vegetation dynamic

[86]

Effects of forest changes on streamflow in three large forested watersheds, southeastern China

Wenfei Liu[1], Xiaohua Wei[2]

[1]Institute of Ecology & Environmental Science, Nanchang Institute of Technology, Nanchang 330099, China
[2]Earth and Environmental Science Department University of British Columbia (Okanagan), 1177 Research Road, Kelowna BC V1V 1V7, Canada

Abstract:

The hydrological effects of forest changes on streamflow in large watersheds are not consistent and require more case studies to support watershed management. In this study, three large watersheds including the Meijiang (6983.20 km^2), Pingjiang (2689.20 km^2) and Xiangshui watersheds (1758 km^2) in the upper reach of the Poyang Lake basin were selected because of drastic forest changes during the past decades and the availability of long-term hydrological data (1956-2006). Time series analysis and hydrological graphical methods were used to assess the effects of forest recovery on streamflow using 50 years of data. Our results show that forest changes produced significant impacts on annual mean flows in all three studied watersheds. Two breakpoints (in 1968 and 1985) were detected in the Meijiang watershed, while only one breakpoint was found in the Pingjiang and Xiangshui watersheds (1965 and 1968, respectively). Forest change has caused significant alterations to most characteristics (e.g. magnitude, timing and duration) of high flow in the Meijiang watershed. However, only timing and duration of high flow were significantly altered in the Pingjiang watershed. There were no significant impacts on any components of the high flow regime in the Xiangshui watershed. Compared to the response of high flow regimes to reforestation, lower and inconsistent impacts on low flow regimes caused by forest changes were found. The different responses to forest changes in the three watersheds demonstrate that hydrological effects in large watersheds are watershed specific. Implications of these results are discussed in the context of climate change, reforestation and water resource management.

Key words: forest changes; streamflow; high flow; low flow; large watersheds

[87]

An ensemble analysis of forest fuel moisture responses to climate change in the continental U.S.

Yongqiang Liu[1]

[1]Center for Forest Disturbance Science, USDA Forest Service, 320 Green Street, Athens, GA 30602, U.S.A.

Abstract:

Forest fuel moisture is the moisture content of organic fuels that is controlled entirely by exposure to environmental conditions. This eco-hydrological property is an important factor for fire weather, fire behavior, and smoke dynamics. Fuel moisture is expected to change significantly in response to projected changes in climate. This study provides projections of fuel moisture changes by the mid-21st Century in the continental United States. Fuel moisture was estimated using the U.S. National Fire Danger Rating System. Climate change scenarios were obtained using dynamical downscaling provided by the North American Regional Climate Change Assessment Program (NARCCAP). Results show general drying trends in fuel moisture conditions across the continental U.S. and large geographical variability, with the largest changes modelled in the western U.S. Seasonal variations are also noticeable. The magnitude and spatial and temporal patterns in fuel moisture respond differently to different climate change scenarios. Ensemble analysis was conducted based on multiple scenarios, to provide an average picture and a measure of uncertainty. Drying fuel moisture trends are very likely to lead to increased future wildfire activity in the continental U.S.

Key words: fuel moisture; climate change; drying condition; CONUS; ensemble analysis

[88]

Application of process-based modelling to assess peak and low flow response to timber harvest scenarios in a mountain watershed

Ryan J. MacDonald[1], Axel Anderson[1], Uldis Silins[2], James Craig[3]

[1]Foothills Research Institute, Canada
[2]University of Alberta, Canada
[3]University of Waterloo, Canada

Abstract:

Forest harvesting, insects, disease, wildfire, and other disturbances can combine with climate change to generate unknown impacts on the amount and timing of streamflow from critical forested watersheds. Southern Alberta forested and alpine areas provide water supply to downstream agriculture and water utilities serving approximately two-thirds of the Alberta population. This project uses datasets from intensely monitored study watersheds and hydrological model platforms to extend our understanding of how disturbances and climate change may impact various aspects of the streamflow regime that are important to downstream users. The objectives are: 1) to use model outputs of watershed response to disturbances to inform assessments of forested watersheds in the region; and 2) to investigate the use of a new flexible modelling platform as a tool for detailed watershed assessments and hypothesis testing.

We applied the RAVEN hydrological modelling framework to quantify peak and low flow responses to timber harvest scenarios in a headwater catchment along the eastern slopes of the Rocky Mountains. The model simulated a 100-year time series generated with a numerical weather generator. Timber harvest scenarios were developed to estimate the effects of cut levels ranging from 20 to 100% over a range of elevations, slopes, and aspects. We quantified changes in the timing, frequency, and magnitude of peak and low flow for all harvest scenarios. We also applied a novel tracer modelling approach to assess runoff generation, demonstrating where water is being contributed from during peak and low flow events. This study provides valuable information and a framework to help guide forest development planning decisions where detailed assessments of hydrological risk are necessary.

Key words: timber harvest; peak flow; low flow; runoff generation; watershed assessment

[89]
Okanagan fish water management tool (FWMT)

Dawn Machin[1]

[1]Okanagan Nation Alliance, Canada

Abstract:

The Okanagan basin is managed via a series of dams to balance between flooding, agriculture and urban water supply, fisheries, and other interests. The challenges faced by water and fisheries managers include variation in seasonal flow, competing objectives and communication barriers.

The Canadian Okanagan Basin Technical Working Group (COBTWG) was formed in 1996 to address salmon stock and habitat restoration issues in the Okanagan, with an emphasis on ecosystem management. Members include the Okanagan Nation Alliance, the Canadian Department of Fisheries and Oceans, and the BC Ministry of Forests, Lands and Natural Resource Operations. The COBTWG identified a number of potential projects to benefit Okanagan sockeye. The FWMT was the preferred option, which was then funded by the Douglas County Public Utility District.

The Okanagan Fish-Water Management Tool is an online, decision-support tool used by fisheries and water managers to balance competing water resource use in the Okanagan basin. The FWMT utilizes 6 linked biophysical models (water supply, water management rules, water temperature, kokanee egg-to-fry emergence, Rocky Mountain ridged mussel, and sockeye submodels) to predict the outcomes of water management scenarios (weekly releases). The predictions and the potential impacts of scenarios are then discussed by water and fisheries managers, and implemented by the regulating agency.

The FWMT has been in use for 12 years, and is instrumental in balancing the competing uses of the limited water supply of the Okanagan basin. In particular, fish-friendly lake levels and flows reduce negative impacts to fish populations.

Key words: water supply; model; ecosystem

[90]

Dissolved organic and inorganic carbon flux from forested mountain watersheds in southern New Zealand

Sarah M. Mager[1], Emily E. Diack[1]

[1]Department of Geography University of Otago, Dunedin, New Zealand

Abstract:

There is a paucity of research to date that has investigated what effect differences in natural vegetation cover, climate and geomorphology has on nutrient systems of forested mountain watersheds in New Zealand, and how these nutrients (primarily N, P, C and Si) are essential for sustaining and maintaining freshwater and marine ecosystems. Dissolved organic carbon is an important component of water quality, regulating water acidity and biological activity, but is rarely monitored as a part of water quality in New Zealand. This paper reports on the flux of dissolved carbon (organic and inorganic) from 70 watersheds across the Southern Alps of New Zealand. These watersheds represent a variety of different scaled watersheds, and distinct climates (high rainfall western watersheds, and lower rainfall eastern watersheds), as well as different scales of indigenous evergreen forest cover and indigenous grasslands. The concentration of dissolved organic carbon (DOC) and dissolved inorganic carbon (DIC) under base flow conditions was measured approximately every 3 months from January 2012 to November 2014. Preliminary analysis shows that the concentration of DOC from the high rainfall western watersheds is 2.5 mg/L, compared to 2.0 mg/L for the drier eastern watersheds. There appears to be no difference in the concentration of DOC with watershed scale, with watersheds smaller than 100 km² averaging 2.3 mg/L, which is the same as watersheds greater than 500 km². Stream order, however, may influence DOC concentrations, with lower concentrations observed in stream orders 3 and 4 compared to 5 to 7. Concentrations of dissolved inorganic carbon (principally as bicarbonate) are not influenced by watershed scale, climate, or stream order, but are a function of underlying geology and related to rates of tectonic uplift and fresh mineral surface exhumation from landslides.

Key words: dissolved organic carbon; inorganic carbon; southern alps; New Zealand; carbon flux

[91]

Impacts of climate and catastrophic forest changes on streamflow and water balance in a mountainous headwater stream in southern Alberta

Vinod Mahat, Axel Anderson

Department of Renewable Resources, University of Alberta, Edmonton, Canada

Abstract:

Rivers in southern Alberta are vulnerable to climate change because much of the river water originates as snow in the eastern slopes of the Rocky Mountains. Changes in likelihood of forest disturbance (wildfire, insects, logging, etc.) may also have impacts that are compounded by climate change. This study evaluates the impacts of climate and forest changes on streamflow in the upper parts of the Oldman River in southern Alberta using a conceptual hydrological model, HBV-EC (Hydrologiska Byråns attenbalansavdelning, Environment Canada) in combination with a stochastic weather generator (LARS-WG) driven by global climate model (GCM) output climate data. Three climate change scenarios (A1B, A2 and B1) were selected to cover the range of possible future climate conditions (2020s, 2050s, and 2080s). The GCM projected less than a 10% increase in winter precipitation and a similar amount of precipitation decrease in summer. These changes in projected precipitation resulted in up to a 200% (9.3 mm) increase in winter streamflow in February and up to a 63% (31.2 mm) decrease in summer flow in June. Flow also decreased in July and August, when irrigation demand is important; reduced river flows during this season could impact agricultural production. The amplification of streamflow is mostly driven by the projected increase in temperature that is predicted to melt winter snow earlier, resulting in lower water availability during the summer. Forest change compounded the impact of climate change by increasing winter flow; however, it did not reduce summer flow.

Key words:

[92]

Evapotranspiration and water use efficiency over eight years following mountain pine beetle attack in lodgepole pine stands in northern British Columbia

G. Meyer[1], T.A. Black[1], Z. Nesic[1], R. Jassal[1], N. Grant[1], D.L. Spittlehouse[3], A.L. Fredeen[2], A. Christen[1], V.N. Foord[3], R. Bowler[2]

[1]University of British Columbia, Vancouver, BC, Canada
[2]University of Northern British Columbia, Prince George, BC, Canada
[3]British Columbia Ministry of Forests, Lands and Natural Resource Operations, Victoria, BC, Canada

Abstract:

Tree mortality due to the recent mountain pine beetle (MPB) outbreak in western North America has impacted hydrology, through increased snow accumulation due to less interception than in healthy stands combined with more rapid snowmelt and reductions in late-summer transpiration.

We made eddy-covariance (EC) measurements of water vapour and CO_2 fluxes over the past eight years in two MPB-attacked lodgepole pine (LP) stands in northern British Columbia, Canada, that were not salvage harvested, and over three years in one stand that was partially salvage harvested (i.e. only dead LP trees were removed) complemented by short-term measurements in nearby clearcuts. One of the not-salvage-harvested stands was an almost pure LP stand with little understory, while the other stand had considerable understory consisting of LP, subalpine fir and white spruce. The partially-salvage-harvested stand originally consisted of 50% LP and 50% spruce and was winter logged.

Our hypotheses were that the not-salvage-harvested stands would initially have significantly reduced evapotranspiration (ET) and be strong annual carbon (C) sources. Instead, our measurements have shown little change in ET following attack in all three stands. The relatively constant ET was likely due to compensating effects of understory transpiration and soil evaporation as the stands recovered. This implies relatively small changes in annual precipitation minus ET, which suggests small effects on runoff and streamflow. Consistent with the small changes in ET, gross ecosystem photosynthesis (GEP) derived from the EC measurements was not greatly affected and slowly recovered over the eight years. Water use efficiency (GEP/ET) ranged from 2.2 to 2.8 g C/(kg H2O) for the almost-pure LP stand and from 1.6 to 2.1 g C/(kg H2O) for the LP stand with considerable understory.

To fully investigate the effects of forest management strategies on water and C balances following MPB attack, we are currently evaluating the process-based model, 3-PG.

Key words: mountain pine beetle; evapotranspiration; water use efficiency; eddy-covariance

[93] Poster

Identification of critical segments on forest roads by LS factor and flow accumulation topographic and hydrological indexes to identify critical segments on forest roads

Frederico Tomas de Souza e Miranda[1], Walter de Paula Lima[1], Silvio Frosini de Barros Ferraz[1], Carolina Bozetti Rodrigues[1], Vanessa Erle Sontag[1]

[1]University of São Paulo, Brazil

Abstract:

Forest roads modify the natural pattern of surface and subsurface drainage and sediment regimes in watersheds. These modifications can degrade aquatic ecosystems and water quality, and as a consequence reduce habitat for aquatic biota. Road maintenance and installation of appropriate drainages features help to mitigate these environmental impacts.

The total length of forest roads in Brazil is greater than 1 million kilometres, primarily as unpaved roads that require more intervention in areas with high rainfall. The aim of this study was to select topographic and hydrological indexes to identify critical road segments. Hydro-geomorphologic effects of forest roads were simulated by lowering of a digital elevation model in order to more realistically represent variability in terrain runoff patterns. The LS factor and accumulated flow were calculated for each of 310 road segments for the State of São Paulo in southeast Brazil. The water volume drained after a 24-hour duration rainfall event with a recurrence interval of 10 years was calculated from accumulated flow. Using both the LS factor and drained water volume, two types of segments were identified based on erosion and water accumulation potential. Results from this study allow prioritization of the most problematic road segments for maintenance and resizing of drainage structures, which will aid in more effective mitigation of environmental impacts caused by forest roads.

Key words: forest roads; LS factor; flow accumulation; hydrological index and topographic index; erosion; digital elevation model; runoff; maintenance; unpaved roads

[94] Poster
Natural forest scenarios and hydrological responses in an agricultural watershed in Brazil

Paulo Guilherme Molin[1], Danielle Bressiani[2], Carla Cristina Cassiano[1], Silvio Frosini de Barros Ferraz[1]

[1]ESALQ/University of São Paulo, Brazil
[2]EESC/ University of São Paulo, Brazil

Abstract:

Forest cover in a watershed can interfere with many hydrological indicators. In this study we highlight native vegetation cover and its importance for ecosystem services of a water regulating nature. Regulation of river flow and water yield are clear examples of this support given by forests and native vegetation, and are also current topics of great importance in the Atlantic Forest region of the State of São Paulo, Brazil. In this study, we selected the Piracicaba River basin as a study region. We projected forest cover scenarios and their effects on regulating ecosystem services linked to water yield and regulation. Historic land cover maps from 2000 to 2010 were used to project scenarios of forest cover increase into the next four decades, using Dinamica EGO software, weights of evidence method and collections of anthropogenic, environmental and physical drivers. Scenarios used were: status quo (SQ), no deforestation (ND) and riparian restoration enforcement (RRE). In the first scenario, observed tendencies were replicated; in the second, the SQ scenario was repeated but without a forest suppression effect; and in the third, all riparian buffer zones were applied to the last observed land cover map. We then calibrated a hydrological model (SWAT) using land cover observed in 2010, and then ran the model with the proposed scenarios, comparing modelled mean annual water yield and regulating hydrological indicators. Final forest cover for the SQ scenario was 22.4% in 2050, for ND it was 43.2%, and for RRE it was 28.4%, compared to an observed cover of 21.8% in 2010. Mean annual water yield decreased as forest cover increased, and flow peaks were attenuated. Thus forests regulated hydrology but reduced total water yield.

Key words: Atlantic forest; forest scenarios; SWAT model; water yield; flow peaks

[95] Poster

The response of alpine meadow soil middle elements to human disturbance in Wugong Mountain

Dekui Niu[1,3], Zhi Li[1,2], Wenyuan Zhang[1,2], Ling Zhang[1,2], Guo Xiaomin[1,2], Yingdan Yuan[1,2], Keyin Sheng[1,2], Gong Xia[1,2,4]

[1]Jiangxi Agricultural University, College of Forestry, Nan Chang 330045, China
[2]Key laboratory of Tree Breeding and Cultivation of Jiangxi Province, Nanchang 330045, Jiangxi, China
[3]Jiangxi Agricultural University, College of Land Resources and Environment, Nan Chang 330045, China
[4]Jiangxi Agricultural University, College of Science, Nanchang 330045, China

Abstract:

Wugong Mountain (approximately 1920 m a.s.l.) lies in Jiangxi province, subtropical China. Alpine meadow ecosystems are estimated to be more than 6000 ha^{-1} on Wugong Mountain, distributed over a large area above the elevation of 1600 m. As a unique landscape in the subtropical area, it attracts a huge number of hiking tourists. Excessive trampling has induced serious soil degradation in meadows, generally followed by ecological problems such as soil fertility decline, nutrient element leaching, etc. In the present study, we quantified the effects of disturbance on soil middle element concentrations. Four disturbance regimes were used: control or no disturbance (vegetation cover 90% to 100%); slight disturbance (vegetation cover 60% to 90%); medium disturbance (vegetation cover 30% to 60%); and severe disturbance (vegetation cover 0% to 30%). The ASI soil nutrient status systematic method was used to measure nutrients in soil samples collected from 0-20 cm and 20-40 cm layers. Results showed that: (1) average concentrations of soil middle element nutrients in Wugong Mountain meadows were 98.66 mg L^{-1}, 15.26 mg L^{-1} and 17.13 mg L^{-1} for Ca, Mg and S, respectively; (2) the concentrations of available S and soil pH were significantly affected by human trampling ($p<0.01$ for both); and (3) soil organic matter and available Mg content differed between soil sampling layers ($p < 0.01$) while Ca, Mg and pH showed no significant difference.

Key words: disturbance; meadows; available Ca; available Mg; available S

[96] Poster
Snow water equivalence (SWE) and soil moisture response to restoration treatments in headwater ponderosa pine forests

Frances O'Donnell[1], Abraham E. Springer[1], Sharon Masek Lopez[1], Temuulen Sankey[1]

[1]School of Earth Sciences and Environmental Sustainability, Northern Arizona University, Flagstaff, AZ, U.S.A.

Abstract:

Forest restoration projects are being planned for large areas of overgrown semi-arid Ponderosa pine forests in the southwestern U.S. Restoration involves thinning of smaller trees and prescribed or managed fire to reduce tree density, restore a more natural fire regime, and decrease the risk of catastrophic wildfire. The goals of these projects include reduced plant water stress and improvements in hydrologic function through enhanced retention of snowpack and soil moisture. However, little is known about how to design restoration treatments to best meet these goals. We measured soil moisture, snow depth, and snow water equivalent in four pairs of control and restored sites near Flagstaff, Arizona. The restoration strategies used at the sites range both in amount of open space created and degree of clustering of the remaining trees. We measured soil moisture through the growing season using 30 cm vertical time domain reflectometry probes installed along 250 ft transects at 25 ft intervals, and measured snow depth and water equivalent at the points where soil moisture probes were installed. Soil moisture was higher and more spatially variable in the restored sites than the control sites, with differences in spatial pattern among the restoration types. Soil moisture was consistently higher under canopies, but snow pack was higher in open spaces. This suggests that reduced evapotranspiration and not increased snowpack is the main mechanism leading to higher soil moisture in restored forests.

Key words: snow, soil moisture, forest restoration, Ponderosa pine, semi-arid

[97]
Conceptual approach to hydrological role evaluation of boreal forest

Alexander Onuchin[1], Tamara Burenina[1], Anastasya Musokhranova[1]

[1]Sukachev Institute of Forest SB RAS, 660036, Academgorodok, Krasnoyarsk, Russia

Abstract:

This research is aimed at clarifying contradictions in explaining the hydrological role of boreal forests. The ambiguity of results from watersheds located in different geographical conditions has served as the basis for the formation of differing (and even contradictory) concepts of the hydrological role of forests. Hydrological cycles were studied at the local level in connection with the specifics of vegetation and climate background. The results allowed us to review the contradictory concepts to develop a conceptual model of geographical determinism that explained regional differences in the impact of forest ecosystems on the structure of the water cycle. We analyzed data on river runoff, precipitation interception by forest canopies and evapotranspiration obtained in a range of environments covering tundra, open woodlands, mountain ecosystems, and taiga biomes.

Studies have indicated that the proportions of rainfall going to evaporation and runoff in the water balance is mainly dependent on peculiarities of the snow moisture balance. In cold climates, decreasing forested area enhances wind-caused snow drifting and sublimation, which decreases runoff. Conversely, forests accumulate and retain moisture, increasing river runoff. In warm climates where forest productivity is high, forests evaporate more water than open area. This is largely attributed to the absence of wind-caused snow drifting and losses to sublimation in open sites, as well as to greater snow interception by closed canopies in these highly productive forests. Under these conditions, forests decrease river runoff. There is a dramatic increase in runoff after forest harvesting, because water budget components such as snow interception and transpiration do not occur on logged sites. During mild winters, sublimation losses from snow surfaces at open sites does not significantly differ from that under forest canopies.

Key words: water balance; runoff; boreal forest; climate; geographical determinism

[98]

Effects of thinning on the under-canopy microclimate in a Japanese cedar plantation, Japan

Kyoichi Otsuki[1], Makiko Tateishi[2], Tamao Kasahara[1], Yuichi Onda[3]

[1]Kyushu University, Japan
[2]Kyoto University, Japan
[3]Tsukuba University, Japan

Abstract:

Thinning is one of the most important forest management practises in Japan because the area of unmanaged mature conifer plantations has rapidly increased in recent years. Although the effects of thinning on tree growth have been widely investigated for forestry, environmental and water resources effects have not been well studied. Thus, we launched a six-year project to study the effect of intensive thinning, 50% by numbers, on ecohydrological processes and water resources in mature plantation catchments. As part of the project, we studied the effect of thinning on the below-canopy microclimate. Air temperature, vapor pressure deficit (VPD), photosynthetic photon flux density (PPFD) and solar radiation (SR) were measured under-canopy and in a nearby open space in three neighboring catchments with different thinning ratios (0%, 35% and 50%) between July and October 2014. Results showed that 1) differences in air temperature among catchments were negligible; 2) differences in VPD among catchments were not significant; but 3) differences in PPFD and SR among catchments were considerably large. The ratios of under-canopy to open space PPFD and SR for each catchment were calculated in the daytime from 10:00 to 14:00. PPFD and SR ratios in the non-thinned catchment were 2% and 3%, respectively, and varied little with weather conditions or season. PPFD and SR ratios under cloudy conditions (only diffuse solar radiation) in the thinned catchments were 9% and 10% for the 35%-thinned catchment, and both 24% for 50%-thinned catchment. These ratios were almost constant regardless of the season. The ratios for all weather conditions including both direct and diffuse solar radiation, however, decreased during winter, and monthly ratios may be calculated by the culmination altitude.

Key words: thinning; microclimate; VPD; PPFD; solar radiation

[99]

Development and testing of a modified transparent head velocity rod (mTHVR) for discharge measurement

Robin G. Pike[1], Todd Redding[2], Carl Schwarz

[1]BC Ministry of Environment, Water Protection and Sustainability Branch. Victoria, BC, Canada
[2]Okanagan College. Department of Geography & Earth and Environmental Science. Penticton, BC, Canada
[3]Simon Fraser University. Department of Statistics & Actuarial Science. Vancouver, BC, Canada

Abstract:

This presentation describes the modification, re-calibration and comprehensive testing of the transparent head velocity rod (THVR). The THVR can be used to measure velocity and depth in wadable streams. In assessing this method for operational application, we found that the calibration equation (Fonstad *et al*., 2005) did not perform well for low head measurements, and instrument deflection occurred at high velocities. In addition, at all depths we observed issues with parallax (image shifting). To address these issues, we modified the THVR using commonly available materials. Subsequent to our modifications, we collected stream velocity and depth measurements over 3 years at 14 sites on Vancouver Island, using a Sontek FlowTracker (FT) and the modified THVR. To assess operator variability, duplicate THVR measurements with multiple operators were made at 13 sites.

From the field data, we generated and validated a revised calibration equation for the TVHR. Two tests (ANCOVA and random effects analysis) were used to investigate potential operator effects at different depths and flow velocities. We also investigated if the relationship between FT velocity and THVR velocity head were constant at all depths. The results showed that our modifications increased the performance of the THVR by minimizing differences with the FT.

The modified THVR trials demonstrated that it should only be used in wadable, laminar to semi-laminar flows suited to the velocity-area approach. We recommend the tool not be used in turbulent streams, at depths greater than 0.75m, or in conditions where velocity-head is outside the tested range due to the increased level of uncertainty in these measurements. The results of this study demonstrate that the modified THVR shows great promise as an inexpensive (< $100), rugged and accurate tool for streamflow measurement.

Key words: velocity-head; velocity; discharge; velocity-area; depth

[100] Poster

Investigation of effective parameters on flood wave celerity in mountain rivers with irregular compound sections

Mohammad Reza Pirestani[1], Akram Gashtasebi[2], Mohammad Reza Majdzadeh Tabatabai[3]

[1]Department of Civil Engineering, Islamic Azad University-South Tehran Branch, Iran
[2]Water Engineering, Islamic Azad University-Eslamshahr Branch, Iran
[3]Department of Water and Environmental Engineering, Shahid Beheshti University, Iran

Abstract:

Every year, floods in vegetated mountain rivers destroy downstream catchment areas. Research indicates that for proper catchment management, the effects of geometric-hydraulic parameters of catchment area branches must be understood. Most research has focused on flood depth, especially in the floodplain, and little research has been performed on flood wave celerity, especially in mountain rivers with irregular compound sections. Because flood waves in mountain rivers are a kinematic wave type and flood wave transmission from upstream to downstream is affected by the wave direction and celerity, such floods are characterized by high peak discharge with short duration. Therefore, understanding the parameters that control flood wave celerity is of utmost importance. For this purpose, a portion of the vegetated Abnick Mountain River in the Jajroud catchment, northern Iran, having irregular compound sections, was selected and studied. Mapping and sampling of bed material and velocity was performed at 28 different cross-sections. Analytical methods and sensitivity analysis of effective parameters were used to evaluate flood wave celerity in this vegetated mountain river with irregular compound section. Results will be presented in detail in this paper.

Key words: mountain river; wave celerity; compound section; irregular section; floodplain

[101]

Bankfull-discharge estimation and determining of regime relation for mountain river (Case study: Ab Nik River)

Mohammad Reza Pirestani[1], Mohammad Reza Majdzadeh Tabatabai[2], Akram Gashtasebi[3]

[1]Department of Civil Engineering, Islamic Azad University-South Tehran Branch, Iran
[2]Department of Water and Environmental Engineering, Shahid Beheshti University, Iran
[3]Water Engineeing, Islamic Azad University-Eslamshahr Branch, Iran

Abstract:

Understanding the parameters that influence flood damage in vegetated mountain river systems is of great importance. This requires knowledge of bankfull discharge and regime relationships due to the effects of large longitudinal slopes, V-shaped valleys and asymmetric compound sections. The vegetated, mountainous Ab Nik River in the Jajroud catchment, northern Iran, was selected for study. Cross-sections and the longitudinal bed profile was mapped for a 200 m long interval of the river. Velocities were measured at each cross-section, and bed materials were surveyed. By comparing width with flow depth at each cross-section, bankfull-discharge was determined using hydraulic equations. Using the obtained values, regime relations for the effective parameters determining the bankfull state in mountain rivers were obtained. Results will be presented in this paper.

Key words: bankful;,mountain river; regime relationship; discharge; hydraulic equations

[102]

Modifying the soil temperature module in SWAT for application in Atlantic Canada: Module development, validation and impacts on watershed modelling

Junyu Qi[1], Sheng Li[2], Qiang Li[3], Zisheng Xing[2], Charles Bourque[1], Fan-Rui Meng[1]

[1]Faculty of Forestry and Environmental Management, University of New Brunswick, Fredericton, NB, Canada
[2]Potato Research Centre, Agriculture and Agri-Food Canada, Fredericton, NB, Canada
[3]Department of Earth and Environmental Sciences, University of British Columbia, Kelowna, BC, Canada

Abstract:

Accurate estimates of soil temperature for hydrological and water quality models is of particular importance for its role in hydrological and biological processes. Soil temperature predictions by the widely used integrated hydrology model Soil and Water Assessment Tool (SWAT) are largely incorrect when applied to regions with significant snow cover. In this study, a new soil temperature module is developed and integrated with SWAT as a substitute for the original empirical formulation. The new module does not require additional inputs for SWAT. The modified SWAT has been calibrated and validated for the Black Brook Watershed, a small watershed in Atlantic Canada. Results indicated a great improvement in predicting soil temperature, particularly in the prediction of winter-time soil temperature. Model predictions are consistent with soil temperature measurements in validation sessions. Further improvements in prediction accuracy could be achieved by improving representation of snow accumulation and melting in SWAT. The modified SWAT was then applied to simulate discharge and sediment N and P loadings in the Black Brook Watershed. Results showed that the modified SWAT improved the accuracy of modelled baseflow and nitrate loading during winter time compared with the original SWAT. The new soil temperature model is crucial for SWAT applications in areas like Atlantic Canada, where the insulating effect of thick snowpacks is so dominant that inaccurate representation of the physical processes of heat transfer along snow covered soil profiles could introduce large biases in modelled soil temperature.

Key words: Soil and Water Assessment Tool (SWAT); soil temperature; modification; Atlantic Canada; watershed modelling

[103] Poster
Limitations on the use of chloride mass balance to estimate of long-term root zone drainage and groundwater recharge on the sub-humid Boreal Plains, north-central Alberta

Todd Redding[1]

[1]Okanagan College, Penticton, BC, Canada

Abstract:

The landscape of the Boreal Plains is a complex mosaic of surficial materials and vegetation types which control the amount, depth and direction of water movement. Understanding spatially varying rates of groundwater recharge in these low-relief, groundwater dominated landscapes is necessary to support water resource management and predict the effects of disturbance. The chloride mass balance (CMB) method was used to estimate long-term rates of root zone drainage and groundwater recharge at the Utikuma Region Study Area (URSA) in north-central Alberta, Canada. The CMB method has been widely applied in arid and semi-arid climates, but rarely in sub-humid climates and northern landscapes. Chloride concentrations were measured in groundwater, unsaturated soil pore water and precipitation for forested sites with coarse (sand) and fine (loam) textured soils. Root zone drainage estimates at the sandy sites were 0-5 mm/yr, which are much lower than hydrometric and modelling results. The loam soils had estimated drainage rates of 1-15 mm/yr, which are similar to hydrometric measurements. The differences between fine and coarse textured soils is opposite to what would be expected based on the water holding capacity of the different soils. Recharge estimated using groundwater chloride concentrations at the fine-textured site ranged from 45-503 mm/yr, and was much greater than would be reasonably expected based on hydrometric methods and modelling. Results highlight the limitations of the CMB method in this landscape, including: (1) lateral groundwater flow from wetlands to uplands; (2) the relatively young surficial materials not being at geochemical steady-state; (3) uncertainty in precipitation chloride inputs; and (4) the effects of past wildfires on soil chemistry. If these limitations can be addressed, the CMB method could provide a low cost and powerful tool for estimating recharge rates on the Boreal Plains.

Key words: recharge; soil texture; soil moisture; groundwater; chloride mass balance

[104] Poster
The Compendium of Forest Hydrology and Geomorphology in BC

Todd Redding[1], Robin Pike[2], Rita Winkler[3], R.D. (Dan) Moore[4], Kevin Bladon[5]

[1]Okanagan College, Penticton, British Columbia, Canada
[2]BC Ministry of Environment, Victoria, British Columbia, Canada
[3]BC Ministry of Forests, Lands and Natural Resource Operations, Kamloops, British Columbia, Canada
[4]University of British Columbia, Vancouver, British Columbia, Canada
[5]Oregon State University, Corvallis, OR, U.S.A.

Abstract:

In 2004, a group of watershed scientists from FORREX, academia, government, and the private sector gathered at the University of British Columbia to discuss the need to document the history, scientific discoveries and field expertise gained in watershed management in BC. This meeting resulted in an outline for a provincially relevant summary of hydrology, geomorphology, and watershed management and work began on the Compendium of Forest Hydrology and Geomorphology.

As a synthesis document, the Compendium consolidates current scientific knowledge and operational experience into 19 chapters with contributions by more than 60 authors. To ensure reliable, relevant, and scientifically sound information, all chapters were extensively peer reviewed employing the standard double-blind protocol common to most scholarly journals. Chapters in the Compendium summarize the basic scientific information necessary to manage water resources in forested environments, explaining watershed processes and the effects of disturbances across different regions of the province. While the Compendium was designed with a regional focus, much of the material is applicable to diverse landscapes and regions. At over 800 pages, the Compendium showcases the rich history of forest hydrology, geomorphology, and aquatic ecology research and practice in British Columbia and sets forth the foundation for the future by showing us how much more we have yet to learn.

Key words: forest hydrology; geomorphology; disturbance; watershed management; synthesis

[105]
The Watershed Status Evaluation Protocol (WSE): An approach to evaluating risk and condition in BC's watersheds with fish values

Lars Reese-Hansen[1], Darcy Pickard[2]

[1]FLNRO (BC Government), Canada
[2]ESSA Technologies, Canada

Abstract:

Under British Columbia's Forest and Range Practices Act (FRPA), the Oil and Gas Activities Act and Land Act statutes, the provincial government can provide legal protection to watersheds with fish values and inherent geomorphic sensitivities that may impact fish values. To ensure the effectiveness of related government objectives and land use practices, a Forest and Range Monitoring Program (FREP) protocol is in the final stages of development. The protocol is used to evaluate whether critical watershed processes and associated resource values are being maintained within watersheds with important fish values. By adapting existing protocols, and creating purpose-built protocols, over the last several years government researchers have been working with a range of partners to develop the Watershed Status Evaluation protocol (WSE). The WSE uses a two-tiered approach: Tier I is a GIS analysis of risk, and Tier II is a field-based assessment of condition. Tier II field sample sites are selected using a spatially balanced randomized frame to determine the condition of: the riparian zone/stream-channel; sediment generation/delivery processes associated with roads and similar structures; and the ability of stream crossing structures to provide connectivity (e.g. fish passage). The focus of this presentation will be on the Tier II field-based portion of the protocol, describing methods and results of applications at watersheds in BC's coastal and interior regions. More information can be found on the FREP fish-watersheds webpage: http://www.for.gov.bc.ca/hfp/frep/values/watershed.htm

Key words: watershed monitoring; risk; condition; fish; land use

[106] Poster
Geographical modeling of spatial interaction between human activity and forest connectivity in an urban landscape of southeast China

Yin Ren[1]

[1]Key Laboratory of Urban Environment and Health, Key Laboratory of Urban Metabolism of Xiamen, Institute of Urban Environment, Chinese Academy of Sciences, China

Abstract:

Geographical detector models provide a quantitative approach for evaluating spatial correlations among ecological factors, population density and landscape connectivity. Here, we used a geographical model to assess the influence of different gradients of urbanization, human activity and various environmental factors on the connectivity of urban forest landscapes in Xiamen, China, from 1996 to 2006. Our overarching hypothesis is that human activity has modified certain ecological factors in a way that has affected the connectivity of urban forest landscapes. Therefore, the spatiotemporal distributions of landscape connectivity should be similar to those of ecological factors, and can be represented quantitatively. Integral indices of connectivity and population density were employed to represent urban forest landscape connectivity and human activity, respectively. We then simulated the spatial relationship between forest patches and population density with Conefor 2.6 software. A geographical detector model was used to identify the dominant factors that affect urban forest landscape connectivity. The results showed that a distance of 600 m was the threshold of node importance. Mean annual temperature, mean annual precipitation, elevation, patch area, population density and dominant species had significant effects on the node importance. Mean annual temperature was more significant than population density in controlling the spatial pattern of the delta of the integral index of connectivity (dIIC). The spatial interaction between population density and various ecological factors as well as their linearly enhanced or nonlinearity enhanced urban forest landscape connectivity. In conclusion, a combination of graph theory and geographical detector models is effective for quantitatively evaluating interactive relationships among ecological factors, population density and landscape connectivity.

Key words:

[107] Poster
Managing wildfires for water security: a risk-based approach

François-Nicolas Robinne[1], Mike Flannigan[1], Marc-André Parisien[2], Kevin Bladon[3], Caroll Miller[4], Monica Emelko[5], Uldis Sillins[1]

[1]University of Alberta, Canada
[2]Canadian Forest Service, Canada
[3]Oregon State University, Corvallis, U.S.A.
[4]US Forest Service, U.S.A.
[5]University of Waterloo, Canada

Abstract:

When 2.5 billion people globally are struggling to obtain water for their basic needs, science must explore all possible ways to address this problem and all potential threats that could worsen it. Ensuring water security, in other words safe, sustainable and affordable access to water, is one of the biggest challenge for modern resource management. Protecting forested watersheds as providers of clean surface water is an important part of this challenge. Large disturbances, such as wildfires, can impair forest hydrology and compromise both the quality and quantity of the water supply to downstream ecosystems and communities.

To reinforce a growing field of fire science focusing on wildfire effects on the water cycle, we present a conceptual approach underlining the need to assess fire risks in water security analyses. Moreover, we argue that the development of a spatially explicit framework could allow for a multi-scale risk assessment, and consequently a rationalization of mitigation actions that will translate into improved protection of water supply.

In the current context of a global water crisis, both climate change and human population growth are likely to impact water and fire regimes in the near future, in ways that are not fully understood and leading to unprecedented conjunctions of water shortages and catastrophic fires.

In this document, we argue that wildfires must be considered as a serious risk to the future of global and local water security, and that the development of risk-based tools must be supported to address it.

Key words: wildfire risk; water security; risk-based management; spatial framework

[108]
Provincial-scale assessment of fire risks to water resources in Alberta

François-Nicolas Robinne[1], Mike Flannigan[1], Marc-André Parisien[2], Kevin Bladon[3], Caroll Miller[4], Monica Emelko[5], Uldis Sillins[1]

[1]University of Alberta, Canada
[2]Canadian Forest Service, Canada
[3]Oregon State University, Corvallis, U.S.A.
[4]US Forest Service, U.S.A.
[5]University of Waterloo, Canada

Abstract:

Regional-scale assessment of disturbance is critical to identify risks to forested river basins, especially in areas where the level of disturbance might compromise ecosystem services such as the reliable supply of water to communities and ecosystems. The present study focuses on the province of Alberta, Canada, where wildfire activity has been judged a potential threat to drinking-water supply. Indeed, almost 70% of the provincial population relies on surface freshwater coming from forested sources. Moreover, shifts in fire activity due to climate change and population growth in the province might increase the fire risk level and consequently the pressure on water resources.

Using a geostatistical approach, we first modeled the potential area burned in Alberta, based on climate and fire activity records over the 1931-2010 period. Then, we overlay these predictions with several hydrographic indices, such as stream network density, to evaluate fire risk levels to the available water resource.

Our results show a large spatial variability in risk prediction in the province, with two main trends. First, there is a high risk in the Rocky Mountains, which has a rather low fire hazard but very high and clustered water resources, meaning that even small but frequent and severe fires could significantly impact the water supply. Second, there is a high risk in the northern boreal forest, which is mainly related to fire activity rather than the density of water resources.

We believe that this regional approach, as part of a multi-scale risk assessment framework, is key for identifying risk hot-spots and then to target watershed-scale studies. Consequently, a rationalization of mitigation actions will translate into better protection of the potable water supply.

Key words: wildfire hazard; water resources; spatial modeling; risk management

[109] Poster
Fast growing Eucalyptus plantations and water: what we already know from Brazilian experiences

Carolina Bozetti Rodrigues[1], Carla Cristina Cassiano[1], Silvio F.B. Ferraz[2], Walter de Paula Lima[2]

[1]Forest Resources Graduate Program, University of São Paulo, Brazil
[2]University of São Paulo, Brazil

Abstract:

Eucalyptus plantations in Brazil cover an area of more than 5 million hectares. However, their effects on water resources are not well known. There is a lack of studies in Brazil on this issue, which does not permit a consensus about the water use of fast growing eucalyptus plantations. For this reason, a thorough review of published studies on this subject will probably contribute to a better understanding of the hydrology of forest plantations. This review will focus on papers that quantified the water balance of planted forests, either through direct measurements in experimental watersheds or estimates obtained by hydrological modelling or sap flow meters. An analysis will be performed to understand the relation between precipitation and evapotranspiration of these plantations. The results will detect trends or generalizations about water consumption of planted forests in Brazil. Besides this, the results can also contribute to improve forest management practices for water conservation. In addition, this study will identify gaps in knowledge and assist in prioritizing research topics, thus contributing to the hydrological sustainability of eucalyptus plantations.

Key words: Eucalyptus plantation; water quantity; forest management; water use; hydrology

[110] Poster
Effects on water quality from timber harvesting and growing of Eucalyptus plantation

Carolina Bozetti Rodrigues[1], Silvio F.B. Ferraz [2], Walter de Paula Lima[2], Arthur Vrechi[3]

[1]Forest Resources Graduate Program, University of São Paulo, Brazil
[2]University of São Paulo, Brazil
[3]Forestry Science and Research Institute – IPEF

Abstract:

We analyzed the effects of timber harvesting and growth of eucalyptus plantations on water quality at an experimental watershed for five years. The study area (75.2 ha) was covered with Eucalyptus plantation (62.8%) and native vegetation around streams (37.2%), with shallow soil (<40cm) and intermittent streamflow. Water samples were collected to determine monthly average concentrations of nitrate, phosphorus, potassium, calcium, magnesium, suspended sediment, turbidity and color. Comparing pre- and post-harvesting annual averages, we found significant differences for calcium and magnesium concentrations (35.7% and 43.9% higher, respectively). nnual average concentrations in post-harvest years (2nd, 3rd and 4th) were compared to annual average values in the year before harvesting (BH). The BH year was assumed to represent best conditions, considering soil protection and the absence of forest operations. The second year after forest harvesting showed significant differences in magnesium (28.9% higher) and in the third year nitrate was different (53.6% lower). In the fourth year after harvesting, there were no significant differences in any variables. Although it was expected that forest harvesting caused changes in hydrological dynamics at a watershed scale, our results showed that these changes can be minimized depending on how forest management is carried out, and that proper management could facilitate the return to pre-harvesting conditions. In other words, resetting time depends on planning and the quality of forest operations.

Key words: eucalyptus plantation; water quality; forest management; watershed; hydrology

[111] Poster

Estimating annual loss and annual evapotranspiration in forested headwater catchments: Analysis of the short-term water balance in pre- and post-thinning

Kimika Sano[1], Takashi Gomi [1], Takanori Sato[2], Marino Hiraoka [1], Yuichi Onda[3]

[1]Tokyo University of Agriculture and Technology, Japan
[2]The University of Tokyo, Japan
[3]University of Tsukuba, Japan

Abstract:

To examine the responses of a catchment water balance to forest thinning in various sizes of headwater catchments, we estimated annual loss and annual evapotranspiration using the short-term water balance method and nested observations for catchments ranging in size from 3 to17 ha. We also selected two adjacent catchments with 40- to 50-year Japanese cedar (*Cryptomeria japonica*) and cypress (*Chamaecypanis obtuse*) plantations in the Tochigi Prefecture, central Japan. A strip thinning with skid trail installation was conducted in the ST catchment between June and October 2011. A random thinning was conducted in the RT catchment between January and February 2013. Thinning intensity for both treatments was 50% by stem density, with 46 % in ST and 24 % in RT of stem volume. Both catchments are composed of chart and sandstone. We monitored stream flow and precipitation from April 2010 to December 2014, and calculated daily values. The maximum values of water loss during 4 months of summer after forest thinning were 50% lower than in the same season before thinning, and estimated water loss as evapotranspiration responded differently among nested catchments. These responses suggested that internal hydrological processes which altered water loss differed depending on the nested catchment. Analysis has been continuing, and we will discuss catchment scale effects, forest management, and resultant changes in evapotranspiration and runoff.

Key words: annual loss; annual evapotranspiration; short-time period water-budget; forest thinning

[112]

The impacts of a changing climate on water supply and flood mitigation in forested headwater catchments

Gebhard Schüler[1], Vu Thi Bich Hong[2]

[1]Research Institute for Forest Ecology and Forestry Rheinland-Pfalz EU-ForeStClim-management; Hauptstrasse 16, D-67705 Trippstadt, Germany
[2]ForeStClim-Project, Hauptstrasse 16, D-67705 Trippstadt, Germany

Abstract:

Climate change has serious impacts on forest functions and spatial and temporal aspects of the water balance in catchments. Hence, combined forest and watershed management in a changing climate is a crucial concern for people and society. In the European project ForeStClim, we investigated forest, soil and water interactions in two different forested headwater catchments with series of irrigation experiments and soil physical measurements. These hydrological investigations were used to calibrate the watershed model ArcAPEX for assessing the risk of both future drought and (flash) flood generation. Based upon a recent reference period (1971–2000), scenarios were modeled for a near (2021-2050) and far future (2071-2100) with dry-warm and moderate-humid climate projections to assess the range of climate change impacts. Climate-induced landuse change scenarios from coniferous forests to deciduous forests and from deciduous forests to steppe were also modeled.

Our results show that the uncertainty range of different climate scenarios plays an important role on climate change impacts. Assuming two ambivalent climate projections, a wide range in water balance and runoff effects were modelled, with more frequent droughts on the one hand and increased flood generation on the other. Climate-induced landuse change from forest to steppe accelerated runoff, and thus increased the risk of flash floods. The replacement of conifers by deciduous trees was less significant, and under these transitions climate impacts will drive the future water balance.

Therefore, unilaterally oriented management strategies cannot be recommended for an uncertain future. In particular, forest management decisions cannot be anticipated too early in favor of very specific management objectives. Sustainable forestry and preventive flood protection should rather follow the principles of ‘spread the risk’ and flexible ‘no-regret’ decisions in multifunctional forests with a high biodiversity and a prioritization of forest services.

Key words: climate change; drought; flood; landuse management; forestry

[113] Poster
Applications of sap-flux density measurements for monitoring tree water-use in South African catchments

B.C. Scott-Shaw[1], C.S. Everson[2]

[1]Center for Water Resources Research, School of Agriculture Earth and Environmental Science, University of KwaZulu-Natal, Private Bag X01, Scottsville, Pietermaritzburg 3209, South Africa
[2]South African Earth Observation Network (SAEON) P.O. Box 13053, Cascades, 3202, South Africa

Abstract:

For many field and modelling applications, accurate estimates of total evaporation (ET) are required, but are often lacking. Modelled estimates are frequently used without proper validation, and verification of the results is questionable, especially in dynamic and highly-sensitive riparian areas. Although the ET of riparian zone vegetation (phreatophytic species) is a critical component of the overall catchment water balance, it is still poorly understood. Due to the availability of accurate techniques to quantify this large and often poorly understood component of the hydrological cycle, modelled estimates can be improved and therefore better understood, as can direct measurements. There is a need to expand current research and to include the water-use of indigenous trees used in forest expansion, the rehabilitation of degraded lands and the restoration of riparian zones. This paper highlights various sap-flow techniques available in South Africa, provides high frequency observations from a forested riparian area in the Western Cape, South Africa and concludes with the validation of a series of hydrological models. Key findings from this study showed that introduced tree species (*Acacia mearnsii* stand) can use up to five times more water than indigenous tree species. In addition, the three years of observed transpiration (beneficial water-use) data were used to validate *ACRU* and *SWAT* models.

Key words:

[114]
Investigation of the scaling properties of the rainfall runoff generation processes and its relation to nutrient flushing mechanisms in the Oregon Cascade Mountains: A nested approach

Catalina Segura[1], Kevin D. Bladon[1]

[1]Department of Forest Engineering Resources and Management, Oregon State University, U.S.A.

Abstract:

It is widely recognized that high water quality and availability are crucial to society and healthy aquatic ecosystems. However, it remains difficult to predict the quantity of water and the flux of nutrients, solutes, and other contaminants that flow through a given catchment after a storm event. This lack of understanding is particularly challenging for forested headwater streams where hydrometric records (i.e., discharge and precipitation) are sparse. Preliminary results will be presented of a pilot study incorporating hydrometric information, measurements of water stable isotopes as natural tracers, and nutrient concentrations (nitrate and phosphate) over 2 seasons (winter and spring) in 3 nested catchments in the H.J. Andrews Experimental Forest Long Term Ecological Research Site. Previous studies in forested catchments in Oregon have examined hydrologic response and nutrient flushing mechanisms over a single hillslope or catchment. It is anticipated that the degree of hydrologic connectivity or responsiveness of a given catchment will depend on the antecedent soil moisture conditions (i.e. season); this controlling effect is likely to decrease as drainage area increases, such that the degree of connectivity will decrease during dry moisture conditions. This effect is also likely to be most pronounced in smaller catchments. We will also investigate and present preliminary data on the controlling effect of drainage area (i.e. catchment size), the role of preferential flow paths, soil depth, and landslide history as predictors of the transit time of "new water" (water added by a particular rain event). Data from this study will provide the foundation for development of process-based models that explicitly incorporate hydrologic connectivity and its relation to nutrient flushing mechanisms and stream ecology.

Key words: water quality; rainfall-runoff; storm events; hydrologic response

[115]

Derivation, uncertainty, and variance of the calibration factor used in salt dilution flow measurements

Gabe Sentlinger[1], Andre Zimmerman[2], Mark Richardson[3], John Fraser[1]

[1]Aquarius Research & Development Inc., U.S.A.
[2]Northwest Hydraulic Consultants, Canada
[3]University of British Columbia, Canada

Abstract:

The salt dilution tracer method is a relatively convenient and accurate method to measure discharge in turbulent streams and rivers. This method is well suited to sites where a laminar transect for conventional current metering flow measurements is unavailable. However, it is often difficult to determine the quality, or uncertainty, of measurements made using conductivity data alone. The method is also constrained by the amount of salt conventionally required for large flow measurements. Conventional wisdom is to use 2 kg of salt for every cumec of flow. However, this is strictly a function of the signal to noise ratio (SNR). To reduce the amount of salt required and reduce uncertainty, or conversely to decrease the uncertainty in the flow measurement using conventional salt injection concentrations, the ability to quantify and control for sources of error is required. We present our results from uncertainty analysis, and associated metadata requirements, for the slug salt dilution method. There is promising evidence to suggest that 10x less than the conventional dosage can be used with acceptable (<5%) uncertainty. This work is part of the ongoing effort to establish a standard operating protocol (SOP) for salt dilution in British Columbia.

Key words: salt dilution; tracer; hydrography; uncertainty

[116]
Forest carbon and hydrology modeling in a multiple-value management regime

Kelly Sherman[1], Krysta Giles-Hansen[1]

[1] Ecora Engineering and Resource Group, Kelowna, Canada

Abstract:

Resource planners and decision-makers are required to consider a wide range of resource values when developing management strategies. Timber production remains an important consideration; however, other values that forests provide such as the regulation of hydrologic regime, carbon sequestration, alternative land uses, and ecosystem services need to be more thoroughly examined during the planning process.

Ecora Engineering & Resource Group Ltd. is considering multiple values in an optimization forest estate modeling environment as part of the BC Provincial Government's Type 4 Silviculture planning process in the Kamloops Timber Supply Area. The project not only includes standard timber supply values such as wood volume, visually sensitive areas, lakeshore management, community watershed constraints and wildlife habitat indicators, but has also added innovative modeling methods for many other values such as forest carbon, hydrology, economics, range, forest health, and wildfire hazard. Many of these values are difficult to objectively quantify, model and set goals for, but are at least as important as economic and social values when making strategic planning decisions. It is also important to account for the impact of historical development, such as harvesting, linear corridors (highways, powerlines, roads, railroads), mines and urban expansion. The forest estate modelling uses a start date of 1980, and implements historical disturbances until 2014 after which the optimization is implemented for 200 years. The historical footprint enables indicator reporting to account for previous disturbances as well as projections.

This planning process facilitates the exploration of interactions and trade-offs between many important and often competing values, with a view to maximizing overall benefit when developing a silviculture strategy. While this project focused on forestry-based activities, the process can be expanded to account for other resource sectors such as mining, oil and gas, range, and even urban expansion. As the process expands to include a wider range of activities, the framework becomes an effective method of assessing cumulative impacts and risks associated with proposed activities.

Key words: forest carbon; hydrology; modeling

[117] Poster
The rate of soil erosion in a moso-bamboo forest of western Japan: Comparison with a broadleaved forest and a coniferous forest

Yoshinori Shinohara[1], Yuma Misumi[2], Tetsuya Kubota[1]

[1]Faculty of Agriculture, Kyushu University, Japan
[2]Graduate School of Bioresource and Bioenvironmental Sciences, Kyushu University, Japan

Abstract:

In Japan, forests of moso-bamboo (*Phyllostachys pubescens*) have expanded rapidly, replacing surrounding broadleaved and coniferous forests. To evaluate the impacts of these replacements, the soil erosion rate in a moso-bamboo forest was compared with those in an evergreen broadleaved forest and a coniferous forest. We established three plots (2 m^2 area) in each forest. The soil erosion rate in the moso-bamboo forest was significantly smaller than those in the broadleaved and coniferous forests. This suggests that the replacement of broadleaved and coniferous forests by moso-bamboo forests would not increase the rate of soil erosion. For the second half of the experimental period, we removed understory vegetation and litter for two of the three plots in each forest. In the broadleaved and coniferous forests, soil erosion rates for the two plots with the removal treatment were considerably larger than that for the plot without the removal. In contrast, in the moso-bamboo forest, soil erosion rates for the two plots with the removal treatment were comparable with that for the plot without the removal. In addition, there were no considerable differences in graves on the surface and strength of the surface soil among the three forests. Root biomass in the moso-bamboo forest was much larger than those in the broadleaved and coniferous forests. These results suggest a large amount of roots could reduce the soil erosion rate in moso-bamboo forests.

Key words: soil erodibility; bamboo forest; vegetation change; surface flow; root-system

[118] Poster
Correlation between groundwater depth and the natural vegetation in the low reaches of Heihe River

Jianhua Si[1], Qi Feng[1], Haiyang Xi[1], Tengfei Yu[1]

[1]Alashan Desert Ecohydrology Experimental Research Station, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, China

Abstract:

Natural vegetation, as one of the dominant components of an ecosystem, has ecological significance in inhibiting desertification and maintaining the stability of riparian ecosystems in arid regions. The availability of water, especially groundwater, determines the composition, distribution, growth and succession of natural vegetation in arid regions and therefore controls the development and stability of oasis ecosystems.

The core oasis in the lower reaches of Heihe River, China, was selected as a study area. Long-term monitoring of oasis vegetation change and groundwater depth allowed quantification of the relationship between the occurrence frequency of plant species and groundwater depth, and the relationship between groundwater depth and mean NDVI in the lower reaches of Heihe River.

Results showed that natural vegetation growth depends strongly on groundwater availability. The relationship between plant species occurrence frequency and groundwater depth indicated that the appropriate depth for vegetation growth in this region is 2.0-4.0 m. This was consistent with results using the relationship between groundwater depth and NDVI measured in 1990, 2001 and 2010, where the appropriate groundwater depth was calculated as 2 to 4.2 m.

There was a direct relationship between groundwater depth and vegetation distribution. However, there is a fine balance between groundwater table being too shallow and too deep. Deep groundwater is not able to supply adequate water to the root system, but with a shallow groundwater depth, salinization will occur at the surface. Therefore, we conclude that there is a limited range of suitable groundwater depths for vegetation development in natural oasis ecosystems of the lower Heihe River.

Key words: NDVI; groundwater depth; oasis vegetation; Heihe River

[119]

A test of selected hydrologic models for operational application in the southern interior of BC

Russell Smith[1], Georg Jost[2], Rita Winkler[3], Dave Spittlehouse[3]

[1]WaterSmith Research Inc., Kelowna, BC, Canada
[2]BC Hydro, Burnaby, BC, Canada
[3]BC Ministry of Forests, Lands and Natural Resource Operations, Kamloops, BC, Canada

Abstract:

Quantifying hydrologic response to forestry practices during cumulative effects assessments is complicated by physiographic and meteorological variability within and between watersheds. Hydrologic models are a means of integrating this complexity into a tool that can be consistently applied. Detailed research models are time consuming to set up and require highly technical expertise to operate, whereas simple models do not represent hydrologic processes adequately to address complex management questions.

The Raven modelling platform (www.civil.uwaterloo.ca/jrcraig/Raven/Main.html) was implemented as part of the Upper Penticton Creek Watershed Experiment to identify an operationally useful hydrologic model to be used by water resource professionals. Raven can be run at any spatial resolution and allows customization of the process representations. To study the effects of forest cover removal, Raven was set up with a canopy representation similar to a research model, while other processes like runoff routing were simplified. Tailoring the model complexity ensured that Raven was easier to set up and ran faster than complex physically-based models (e.g. DHSVM). For this application, the watershed was represented in a semi-distributed fashion using data available in typical operational scenarios. It was calibrated and validated using both snowpack and streamflow data.

The model simulated snowpack water equivalent well throughout snow accumulation and melt phases, and across a range of elevations, forest cover conditions, and slope aspects. It simulated the spring freshet hydrograph well across several years, with the exception of a spring with unusually warm weather resulting in a delayed simulated hydrograph.

A 100 year synthetic meteorological dataset was run through Raven under varying forest cover scenarios. The predicted impacts of forest cover removal on peak flows were quantified using flood frequency analysis (FFA). The results compared favorably with a similar study that used a complex research model (DHSVM), indicating that Raven is a good candidate for operational application.

Key words: runoff modelling; operational testing; flood frequency; cumulative effects assessment; landscape scenarios

[120]
Groundwater-surface water interactions in a Rocky Mountain catchment in Alberta, Canada

Sheena A. Spencer[1], Axel Anderson[2], Uldis Silins[1], Kevin D. Bladon[3], Adrian Collins[4]

[1]University of Alberta, Canada
[2]University of Alberta/Foothills Research Institute, Canada
[3]Oregon State University, U.S.A.
[4]Rothamsted Research, Canada

Abstract:

The eastern slopes of the Rocky Mountains are critical source areas for Alberta's surface water supply. Improved knowledge of groundwater-surface water interactions and temporal and spatial variability of streamflow sources (hillslope, hyporheic, and groundwater) is important for understanding the resistance of catchment runoff response to disturbance. The objectives of this study were to determine if topography, surficial geology, water chemistry, and differential gauging can be used to define contributing areas and possible sources of stream water for a headwater catchment.

The study was conducted in Star Creek (10.4 km^2), a mountainous catchment located in the Crowsnest Pass, Alberta. Six nested hydrometric stations were used to collect 6 years (2009-2014) of stream discharge and water quality data. Topographic upslope accumulated area (UAA) was calculated (Grabs *et al.*, 2010) and shallow groundwater wells were installed in transects from the riparian zone to the upper hillslope. To refine stream water characteristics, the streams were sampled every ~150 m and at areas with visible seeps during 3 flow conditions; samples were analyzed for cation/anion concentrations. Instantaneous differential gauging was conducted on reaches ~500 m in length to define stream reaches that were gaining or losing water. Water chemistry from shallow groundwater wells, suction lysimeters, precipitation, and the flow data were used to characterize source waters, test the UAA conceptual model, and differentiate areas of suspected hyporheic and groundwater flow.

A simple mixing analysis indicated that ~60–70 % of streamflow comes from groundwater. In general, large gaining reaches correspond to locations with large UAA, visible groundwater seeps, and significant changes in stream water chemistry, EC, and temperature. However, groundwater well data indicate that UAA did not correspond consistently with the longest duration of hillslope connectivity. This is likely due to controls from subsurface glacial till and paleo-channels.

Key words: groundwater; streamflow; mountains; chemistry; source water

[121] Poster
20 years of rainfall interception in a young coastal Sitka spruce forest

David L. Spittlehouse[1]

[1]BC Min. Forests, Lands and Natural Resource Operations, Victoria, BC Canada

Abstract:

Interception of rainfall by forests and its evaporation is an important component of the water balance. Throughfall troughs, roving below-canopy storage gauges, and stemflow collars were used to measure how interception changed as a young forest grew. The study took place at the Carnation Creek watershed on the west coast of Vancouver Island, BC, Canada (48°54'N, 125°0'W, 50 m) (mean annual precipitation of 3020±490 mm of which over 95% falls as rain, mean annual temperature 9.8°C). In the mid-1990s, the 20-year old forest (5 to 7 m tall, 1700 stems/ha, 75% canopy cover) had throughfall at 75% and stemflow 9% of the annual rainfall. By 2014, the forest was 15-20 m-tall, 1300 stems/ha, and throughfall had decreased to 70% and stemflow was 8% of the annual rainfall. In the late 1990's stemflow was initiated by storms greater than 3 mm, while by 2014 it required storms of over 6 mm. Consequently, annual interception loss has increased from 16 to 21±4% of the rainfall. Annual interception loss is now similar in size to annual transpiration. The fraction of the storm rainfall intercepted decreases with an increase in storm size. Small storms and warmer conditions in the summer mean that interception is a much greater percentage of rainfall than in winter. Interception loss is approaching that measured in a nearby old growth stand.

Key words: rainfall; interception; stemflow; young forest

[122]

Inter-annual variability in interception, evaporation and drainage from high elevation forest, clearcut and regenerating stands in the interior of BC

David L. Spittlehouse[1], Rita D. Winkler[2]

[1]BC Min. Forests, Lands and Natural Resource Operations, Victoria, BC Canada
[2]BC Min. Forests, Lands and Natural Resource Operations, Kamloops, BC Canada

Abstract:

Twenty four years of weather data were used to assess the effect of changing forest cover on annual site water balance at the Upper Penticton Creek Watershed, British Columbia, Canada. Measurements of snow temperature, depth and ablation, albedo, interception of precipitation, soil moisture and transpiration were used to calibrate a physically-based daily water balance model. October to September evaporation from the forest averaged 390±33 mm, of which 55% was transpiration and 45% intercepted rain and snow. Evaporation from the clearcut was 200±20 mm. Consequently, annual drainage averaged 590±110 mm and 380±100 mm from the clearcut and forest, respectively. Increased drainage from the clearcut is mainly a result of the reduction in interception loss. By 6 years after harvest, transpiration plus soil evaporation from the regenerating stand approximated that from the forest, but interception loss was small. Interception increased as the regenerating stand grew. Inter-annual variability of evaporation was mainly a function of the variation in summer precipitation, while drainage was driven by winter precipitation and spring temperature. Annual evaporation from a forest or clearcut was relatively constant, except for two years with well below average summer rainfall. In these dry summers, evaporation from the clearcut was substantially less than that of the forest and regenerating stand.

Key words:

[123]

Advancing watershed management in British Columbia's Cariboo region: Forest licensee implementation of a risk-based approach to support timber development planning

Randy Spyksma[1], Lars Uunila[2]

[1]Forsite Consultants Ltd., Canada
[2]Polar Geoscience Ltd., Canada

Abstract:

The Cariboo-Chilcotin Land Use Plan requires that watersheds be managed for "hydrologic stability" and/or conservation of salmon stocks. In response, a 25% equivalent clearcut area (ECA) threshold has been broadly used to trigger detailed watershed assessment. While ECA is a simple indicator, it does not correspond well to watershed risk. Tolko Industries Ltd. (Tolko), through an amendment to their Cariboo Woodlands Forest Stewardship Plan (FSP), have developed a more holistic approach to watershed management. This represents a shift from one that is threshold-based to one that is risk-based, which considers both hazards and environmental consequences.

This new approach follows the work of the BC Ministry of Forests, Lands and Natural Resource Operations (BC FLNRO) and its partners to develop a watershed risk analysis framework for the BC Interior. This framework involves a combination of GIS analysis, office review and field observations, and utilizes 14 hazard indicators related to streamflow, sedimentation and riparian function. Based on these indicators and knowledge of the fisheries resource, watershed risk is estimated at multiple scales (e.g. watershed, basin, sub-basin).

One of the main objectives of this project was to leverage the work of BC FLNRO and develop a decision-support tool that Tolko staff could use to assess watershed risk when planning for timber development. Key steps taken to achieve this objective included: 1) refining risk rankings based on the work of Lewis *et al.* (2013); 2) developing a decision matrix to assist in interpretation; 3) developing operational procedures to assessing watershed risks associated with timber development; and 4) identifying a suite of measures to mitigate commonly identified risks (i.e. "risk mitigation toolbox").

This risk-based approach to watershed management has been included in Tolko's recent amendments to its FSP and is currently nearing approval. Further work includes documentation, mapping and GIS, staff training, and follow-up monitoring and review.

Key words: risk analysis; timber; planning; fish; watershed

[124]

Persistence of *Cryptosporidium parvum* in cattle feces in forested environments

Keith Story[1], Deborah Roberts[1], Keith Duhaime[1]

[1]University of British Columbia, Kelowna, Canada

Abstract:

Grazing cattle on forested crown lands is practiced in many municipal watersheds. This activity can be beneficial to the economy of the areas, but may also pose a risk to the drinking water that is extracted from the watershed due to the introduction of pathogens from cow feces. These pathogens may make their way into creeks and streams, potentially transmitting disease to other animals in the watershed and to humans through the drinking water systems. In order to manage this possible disturbance to the watershed, managers need to develop and employ best management practices including prescribing when to allow cattle in the forest grazing land. *Cryptosporidium parvum* is the most prevalent pathogen of concern from cattle grazing. In this study we examine the persistence of *C. parvum* in cattle feces that has been spiked with oocysts of the organism and then deposited in patties. We expected *C. parvum* survival to vary depending on DNA destruction during exposure to sunlight, the inhibition or enhancement of chemical and metabolic process in response to temperature, and exposure to rain. Fecal patties were deposited under conditions to represent the range of sunlight exposures expected in forested crown lands, i.e. full sun exposure (forest clearing), full shade (under a canopy) and partial shade (near the forest-clearing transition). Indices of oocyst survival were determined as the ability to extract and amplify DNA by PCR from samples collected periodically from the patties. We will present the results of this study and conclude with suggestions for fall cattle grazing allowances so as to prevent pathogen contamination of water during the spring freshet period.

Key words: watershed; cattle grazing; Cryptosporidium; pathogens; spring freshet

[125] Poster
Interaction of vegetative patches and soil properties in the valleys of Qilian Mountains

Yong-zhong Su[1]

[1]Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, China

Abstract:

Interactions between plant community succession and soil property changes have significant implications for understanding ecosystem structure and function. In this paper, plant species composition, soil physical and chemical properties and vegetation-soil interactions in a degraded shrub meadow community were investigated in the valleys of the southern Qilian Mountains. At forest edges, plant community patches evolve along a degradation succession from a *Potentilla fruticosa* community, to mixed *P. fruticosa-Iris lacteal* patch, to *I. lacteal* community. Vegetation cover decreased but species diversity increased. There was an evident gradient in soil water content between the vegetation patches, showing that soil water availability resulted in the succession of vegetation community patches. This evolution has a strong influence on soil physical and chemical properties. From a *P. fruticosa* patch to an *I. lacteal* patch, soil bulk density significantly increased; the proportions of larger macro-aggregates (>1mm) decreased, and of small macro-aggregates (1-0.25mm) and micro-aggregates (<0.25mm) increased; and aggregate stability decreased. These results suggest that soil structure degraded with vegetation succession. Soil organic carbon (SOC) decreased by 31.2% and 55.9% in the *P. fruticosa-I. lacteal* and *I. lacteal* patches, respectively, compared to the *P. fruticosa* patch. SOC concentrations in dry-sieved aggregate classes were higher in the *P. fruticosa* patch than in the other two patches. There is a close linear relationship between SOC and the mean weight diameter of dry-sieved aggregates (DMWD). Loss of SOC in the degraded succession is partly due to the breakdown of macro-aggregates. Total and available nitrogen decreased significantly from the *P. fruticosa* patch to the *I. lacteal* patch, but the effect of decreased extent is less than that of SOC, resulting in a decreased C/N in the *I. lacteal* patch. However, no differences in total and available phosphorus and potassium were observed among different vegetation patches. Degradation of soil structure due to macro-aggregate breakdown and decreased SOC and nitrogen availability resulted in decreased resistance to erosion and reduced function for water and soil conservation, and, in turn, further accelerated degradation succession of vegetation. Under increased drought frequency due to global climate warming, *I. lacteal* community patches may further expand toward the forest line, and shrub meadow vegetation may further degrade and contract.

Key words: vegetative patch; community composition; soil aggregate; soil organic carbon; soil nutrient

[126]

A comparison of watershed evapotranspiration estimated by multiple methods across the United States

Ge Sun[1], Shanlei Sun[2], Jingfeng Xiao[3], Peter Caldwell[4], Asko Noormets[5], Devendra Amatya[6], Suat Irmak[7], Prasanna H. Gowda[8], Sudhanshu Panda[9], Steve McNulty[1], Yang Zhang[2]

[1]Eastern Forest Environmental Threat Assessment Center, Southern Research Station, USDA Forest Service, Raleigh, NC 27606, U.S.A.
[2]Department of Marine, Earth, and Atmospheric Sciences, North Carolina State University, U.S.A.
[3]University of New Hampshire, U.S.A.
[4]Coweeta Hydrologic Lab, SRS, USFS, U.S.A.
[5]North Carolina State University, U.S.A.
[6]Center for Forested Wetlands Research, SRS, USFS, U.S.A.
[7]University of Nebraska – Lincoln, U.S.A.
[8]USDA-ARS Conservation and Production Research Laboratory, U.S.A.
[9]University of North Georgia, U.S.A.

Abstract:

Evapotranspiration (ET) is the largest watershed water balance component after precipitation in the United States. ET is closely coupled with ecosystem carbon and energy fluxes, affects flooding or drought magnitude, and is also a good predictor for biodiversity at a regional scale. The ecosystem service functions of ET are often underestimated. Accurately estimating ET is of paramount importance to quantify the effects of land use change and climate change on watershed ecosystem services in water supply, water resources management, carbon sequestration, and biodiversity conservation. However, ET measurement remains an imprecise science, and it is difficult to quantify at the watershed scale. This study compared ET estimates for over 400 watersheds with areas ranging 40 - 25,751 km^2 using multiple independent methods, including: watershed water balance (precipitation–streamflow or P-Q method); up-scaling of eddy covariance flux measurements (AmeriFlux, NEBFLUX) using the regression tree method (EC-MOD); a MODIS based remote sensing approach; and watershed hydrologic modeling (e.g., WaSSI, SWAT). Preliminary analysis showed that there were large discrepancies in computed watershed ET estimates among the selected methods due to different assumptions and limitations. In particular, ET estimated by the eddy covariance method or MODIS products were 25-40% lower than estimates from the P-Q method. The WaSSI model generally over-estimated ET by 20% when compared to the P-Q method (534±196 vs. 487±263 mm/yr, respectively). We discuss the potential causes of the discrepancies found in this study, and methods to improve ET estimates at a watershed scale.

Key words: eddy covariance; evapotranspiration; land use change; water balance; hydrologic modeling

[127] Poster
Impact of strip thinning on forest floor evaporation in a Japanese cypress plantation

Xinchao Sun[1], Yuichi Onda[1], Kyoichi Otsuki Kasuya[2], Hiroaki Kato[1], Takashi Gomi[3]

[1]Faculty of Life and Environmental Sciences, University of Tsukuba, Japan
[2]Research Forest, Kyushu University, Japan
[3]Department of International Environmental and Agricultural Science, Tokyo University of Agriculture and Technology, Japan

Abstract:

The opening of stand canopies due to thinning results in immediate modifications of the environmental factors that greatly influence forest floor evaporation (Ef). Few studies have reported on the impact of thinning on Ef and the forest water cycle. Coniferous plantations in Japan constitute approximately 40% of the forested area. However, little attention has been paid to management practices such as thinning in these plantation forests. Currently, thinning is required to control tree growth and density, and to enhance forest hydrological functions. Therefore, the objectives of the study are to 1) analyze the effect of strip thinning on Ef and its spatial variation, and 2) identify the factors influencing Ef in a Japanese cypress plantation. Strip thinning, which removed 50% of stems, was conducted in a headwater basin in October 2011. Ef was monitored by weighing lysimeters before and after thinning. Results showed that the daily Ef post-thinning was strongly correlated with daily solar radiation, and less strongly correlated with vapor pressure deficit below the canopy, and no significant correlation with soil water content. After thinning, daily Ef had a small spatial variation in response to the low spatial variability of daily solar radiation under the canopy. Additionally, at an annual scale, daily mean and annual total Ef values doubled after thinning. These findings demonstrate that Ef comprises a significant part of the forest water budget after thinning, and emphasize the importance of Ef measurements for management practices. This study also provides useful information for modeling changes in hydrological processes at the forest floor and evaluating effects of different management practices (e.g., selective thinning) on Ef to optimize water yield.

Key words: *Chamaecyparis obtusa*; forest floor evaporation; strip thinning; spatial variation; solar radiation; weighing lysimeter

[128]
A stategic approach to fish passage in BC

Richard Thompson[1], Craig Mount[2], Simon Norris[3]

[1]Ecosystem Conservation Section, BC Ministry of Environment, Canada
[2]Knowledge Management Branch, BC Ministry of Environment, Canada
[3]Hillcrest Geographics, Victoria, BC, Canada

Abstract:

British Columbia is a large province (approximately 1,000,000 km^2) with over 2,000,000 km of streams and rivers. BC also contains a wealth of natural resources and, to access those resources, more than 500,000 km of road have been built. Conservative estimates place the number of crossings at more than 430,000 and many of those we now know are partial or total barriers to fish movement. The result is thousands of kilometers of fish habitat that are no longer accessible

The Province of British Columbia in partnership with the federal government and other organizations has been working on implementation of a strategic approach to better understand the extent of the fish passage problem, and identify and set priorities for restoration.

This talk will provide an overview of that strategic approach, including the assessment techniques utilized. Over 15,000 assessments have been carried out under the BC Fish Passage Program, and while this is a small percentage of the total number of crossings on the landscape it does give us a reasonable sample size from which to draw some meaningful observations. This presentation will provide summary statistics from data collected to date, and highlight some interesting relationships between roads, streams and crossings which fail to pass fish. By using an updated fish habitat model, a more quantitative assessment of the opportunities for regaining habitat is also now possible. The results from this work will also be presented with a look at cumulative impacts.

Key words: fish passage; assessment; cumulative; watershed

[129]

Carnation Creek watershed experiment – Long-term responses of coho salmon populations to historic forest practices

Peter Tschaplinski[1], Robin Pike[2]

[1]Ecosystems Branch, British Columbia Ministry of Environment, Victoria, BC, Canada
[2]Water Protection and Sustainability Branch, British Columbia Ministry of Environment, Victoria, BC, Canada

Abstract:

The Carnation Creek project is a long-term, multi-disciplinary case study of the effects of forestry practices on a small coastal watershed. Located in southwestern Vancouver Island, British Columbia, Canada, Carnation Creek is a small stream (7.8 km length) that drains an area of approximately 11 km^2. Initiated in 1970, the study has an intensive pre-treatment vs. post-treatment-impact design that consists of five years of pre-harvest baseline data, six years of during-logging measurements when 41% of the basin was harvested, and 33 years of post-harvest observations. The study incorporates clearcut and control sub-basins, and riparian forestry treatments along the main stream that vary from intensive clearcutting to a variable-width riparian reserve. Fish population responses to logging have been complex, and both species and life-stage specific. Thermal warming of the stream due to riparian harvest benefited juvenile Coho Salmon for more than two decades by increasing growth and survival in freshwater, and elevating smolt production by 1.6 fold between 1976 and 2004. Thermal benefits counteracted detrimental impacts to stream habitats attributed to riparian clearcutting, which resulted in accelerated bank erosion and collapse, loss of stable in-stream wood, formation of new logjams, and increased levels of streambed scour and downstream sediment transport. These effects were greatly amplified and overwhelmed by the effects of landslides that occurred in 1984. The landslide-related effects took more than 20 years to propagate downstream to cover the entire stream portion inhabited by anadromous salmon. Channel and fish habitat complexity have been greatly reduced, and the streambed is more unstable with accelerated bedload transport. These delayed impacts have reversed short-term, logging-related benefits for Coho Salmon. Fry-to-smolt survival has declined from a mean of 50% between 1982 and 2004 to 15% since 2005. Coho Salmon smolt production has consequently been reduced to below pre-logging levels. These results show that forestry-related impacts may take decades to fully develop.

Key words: watershed; salmon; forest practices; landslides

[130]

Interannual variations of and factors controlling evapotranspiration in a temperate Japanese cypress forest

Kenji Tsuruta[1], Yoshiko Kosugi[1], Satoru Takanashi [2], Makoto Tani[1]

[1]Graduate School of Agriculture, Kyoto University, Japan
[2]Department of Meteorological Environment, Forestry and Forest Products Research Institute, Japan

Abstract:

This study was undertaken to determine the range and controlling factors of interannual variations in evapotranspiration (ET) in a temperate coniferous forest in Japan. We conducted eddy covariance flux and meteorological measurements for 7 years, and parameterized the multilayer soil–vegetation–atmosphere transfer model that partitions ET into transpiration (Tr), wet-canopy evaporation (Ewet), and soil evaporation (Esoil). The model was validated with observed flux data. Using the model, the components of ET were estimated for the 7 years. Annual precipitation, ET, Tr, Ewet, and Esoil over the 7 years were 1536 ± 334 mm, 752 ± 29 mm, 425 ± 37 mm, 219 ± 34 mm, and 108 ± 10 mm, respectively. The maximum interannual fluctuation of observed ET was 64 mm with a coefficient of variation (CV) of 2.7%, in contrast to relatively large year-to-year variations in annual precipitation (CV = 20.1%). Tr was related to vapor pressure deficit, incoming radiation, and air temperature with relatively small interannual variation (CV = 8.2%). Esoil (CV = 8.6%) was mainly related to vapor pressure deficit. Ewet was related to precipitation with large interannual variation (CV = 14.3%) because of the high variability in precipitation. Variations in Ewet were counterbalanced by the variations in Tr and Esoil, producing the small interannual variation in total ET.

Key words: evapotranspiration; soil–vegetation–atmosphere transfer model; eddy covariance; Japanese cypress; water balance

[131] Poster

Back propagation neural network models of sap flow velocity for *Pinus elliottii* in degraded red soil area of Jiangxi province

Jie Tu

Research Institute of Ecology & Environmental Sciences, Nanchang Institute of Technology, Nanchang 330099, China

Abstract

Pinus elliottii is commonly considered to be one of the most important pioneer tree species for forest restoration and reconstruction in subtropical degraded red soil areas of China, due to its high productivity and leanness-resistance. However, they also consume large amounts of water during growth. Quantitative assessment of water consumption by transpiration has become a focus for tree physiological research in recent years. The aim of this study was to sustainably manage *P. elliottii* plantations for water resources.

A neural network model was developed for a *P. elliottii* plantation in a degraded red soil area of Jiangxi province, using the log-sigmoid function (i.e. tansig) in MATLAB software as the action function. Based on correlation analysis, air temperature, relative humidity, average net radiation and vapor pressure deficit were used as input variables and sap flow velocity as the output variable. An optimum 3-layer BP artificial network model for sap flow velocity was established using the topological structure 4-10-1. Individual measurements for 1900 individual trees were used to train the neutral network, for both Bayesian regularization and Levenberg-Marquardt algorithms. An additional 1900 measurements were used to test the model. Linear regressions showed good fits between measured and predicted results for both algorithms ($R>0.98$). Fitting accuracies for the training dataset were 88.12% and 88.11% for the Bayesian regularization and Levenberg-Marquardt algorithms, respectively, and 88.11% and 87.98% for the testing dataset, respectively. The model more accurately describes the non-linear relationship between sap flow velocity and meteorological factors than linear regression models, with better accuracy and generalization.

Keywords: *Pinus elliottii*; sap flow; BP neural network; Bayesian regularization algorithm; Levenberg-Marquardt algorithm

[132]

Effects of reforestation of degraded land on hydrological flow pathways and streamflow in Leyte, the Philippines

H.J. (Ilja) van Meerveld[1], Jun Zhang[2], Kimberley Janzen[3], Jeffrey McDonnell[3], L.A. (Sampurno) Bruijnzeel[2]

[1]Department of Geography, University of Zurich, Zurich, Switzerland
[2]Critical Zone Hydrology Group, VU University Amsterdam, Amsterdam, The Netherlands
[3]School of Environment and Sustainability, University of Saskatchewan, Saskatoon, Canada

Abstract:

The prevailing view amongst forest hydrologists is that differences in stormflow volume and peak discharge between forested and grassland catchments tend to decrease as event precipitation increases, with the difference becoming negligible for the most extreme events. However, most experimental studies on which these views are based were conducted in non-degraded catchments. We set out to study the differences in the hydrological response of a degraded grassland catchment and a semi-mature reforestation (22 years since planting) catchment near Tacloban, Leyte, the Philippines. Stream stage, electric conductivity (EC) and temperature were measured continuously. Precipitation, throughfall, soil moisture and groundwater levels were also monitored. Samples were taken from rainfall, streamflow, groundwater and soil water for chemical and stable isotope analysis. Streamflow increased rapidly, and EC of streamflow decreased markedly during most storm events in the grassland catchment. However, in the reforested catchment, streamflow and EC responses were much smaller and only occurred during larger events. The changes in chemical and isotopic composition of streamwater were also larger in the grassland catchment than in the reforested catchment. These results suggest that overland flow occurred much more frequently and was much more widespread in the grassland catchment than in the reforested catchment. These differences in streamflow response were also observed for extreme events, including super-typhoon Haiyan, which delivered more than 200 mm of rainfall within 2 hours. This remarkable finding is explained by the presence of numerous shallow landslips in the grassland catchment, which resulted in widespread overland flow. These results indicate that dominant flow pathways have changed as a result of reforestation, and suggest that reforestation can largely restore the hydrological functioning of degraded land for all storm event sizes, provided the forest and soil are allowed to develop over a sufficiently long period.

Key words: reforestation; flow pathways; infiltration; overland flow; streamflow

[133]

Evaluating hydrological behavior of a paired catchment study in south of Brazil

Arthur Vrechi [1], Silvio Frosini de Barros Ferraz [2], Walter de Paula Lima [2], Carolina Bozetti Rodrigues[3], Mariane Bueno de Camargo[4]

[1]Forestry Science an Research Institute, Piracicaba, SP, Brazil
[2]University of São Paulo - USP, Piracicaba, SP, Brazil
[3]Forest Resources Graduate Program - USP, Piracicaba, SP, Brazil
[4]Klabin S/A, Telêmaco Borba, PR, Brazil

Abstract:

Forest plantations play important economic and environmental roles in Brazil, especially in regions where economic activities related to wood products and planted forest land use are significant. In these regions, concerns about the hydrological impacts of planted forests are recurrent for local stakeholders. In order to study hydrological impacts and to develop sustainable forest management strategies, a network of experimental catchments over Brazil and Uruguay was established through a partnership among IPEF (Forest Science and Research Institute), USP (University of São Paulo) and forestry companies. Precipitation and stream-gauging stations were set up in each catchment starting in 2006.

No two catchments are equal, and differences were taken into account in the calibration procedure of the paired-catchment experimental design. In an attempt to identify some of the differences in the hydrological behavior of paired catchments, we calculated flow duration curves for high (Q10) and low (Q90) runoff rates, monthly discharge responses to precipitation (Q/P), daily discharge coefficients of variation (CV) and base flow index (BFI) as hydrological indicators. Catchments are located at Paraná State, in Klabin Company forestland, with one catchment covered by native forest (34.4 ha) and the other with a *Pinus* plantation (85% of 121.2 ha). The climate zone is humid subtropical (Cfb), with mean annual precipitation and temperatures of 1444 mm and 18.6°C, respectively. Data for the period 2006 to 2008 were analyzed, when the *Pinus* forest was in its adult stage (7 to 10 years) and without harvesting operations. Paired catchment analysis showed similarities in hydrological processes despite a difference in water yield, due to dissimilarities in land use and also possibly in catchment geomorphological features. High flows (Q10) were 0.67 and 0.47 mm/day for native and *Pinus* forests, respectively, and low flows were 0.12 and 0.08 mm/day, respectively. CV and Q/P were higher for the native forest, indicating that the *Pinus* forest can help to attenuate extreme rainfall events. BFI was similar for both catchments, suggesting related hydrological processes.

Key words: paired catchment; *Pinus* plantation; native forest; hydrological processes; water impacts

[134]

Assessment of forest harvesting and protection of water in community watersheds in British Columbia

Doug Wahl[1]

[1]Manager of Audits and Investigations, British Columbia Forest Practices Board, Canada

Abstract:

In British Columbia, water used for drinking, irrigation and other purposes is obtained from a variety of ground and surface water sources located on private and publicly owned land. Wherever drinking water is sourced from, legislation requires that the water be treated to an acceptable standard. Additional rules apply on public land to ensure that drinking water is not impacted by industrial activities like forestry, oil and gas development or mining. Under the Forest and Range Practices Act (FRPA), all licensees are required to ensure their practices do not harm drinking water, and additional measures are required in 466 designated areas called 'community watersheds'.

In 2014, the Forest Practices Board reported its findings on how well forest licensees were meeting FRPA's requirements to protect drinking water in community watersheds. The Board looked at forest stewardship plans in 48 community watersheds that had recent forestry activity, and assessed compliance with FRPA's requirements on the ground in 12 watersheds. Hydrological assessments prepared for these watersheds, to assess the possible effects of harvesting or road construction, were also assessed.

Overall, the Board found that improvements are required in how forest licensees protect drinking water in community watersheds under FRPA. Commitments to protect drinking water in forest stewardship plans were not always enforceable, and issues were identified in hydrological assessments. In the 12 watersheds examined on the ground, Board investigators found that most licensees were complying with FRPA requirements, but greater emphasis needs to be placed on erosion and sediment control on forestry roads. A key issue in the watersheds was the impact of historical forest harvesting and other development activities that are not subject to the same restrictions as current forestry activities.

Key words: community watersheds; drinking water; forest stewardship

[135] Poster

Observation of canopy interception loss, rainfall distribution and wind effect on rainfall observation in matured beech forest

Taeko Wakahara[1], Yoshiharu Ishikawa[1], Katsushige Shiraki[1], Yoshimi Uchiyama[2]

[1]Tokyo University of Agriculture and Technology, Japan
[2]Kanagawa Prefectural Natural Environment Conservation Center, Japan

Abstract:

Throughfall impacts soil erosion and overland flow in forests. It is known that the throughfall effect is especially important in forests with little understory vegetation, such as abandoned coniferous plantations or deer browsing areas. In these forests, throughfall directly reaches the uncovered soil surface and can easily cause soil erosion. It is important to understand the characteristics of throughfall distribution and canopy interception loss not only to prevent erosion in the forest floor but also for water management.

We observed the distribution of rainfall and wind speed and direction within and outside of a mature beech (*Fagus*) forest on Tanzawa Mountain, Japan, for two years. We also observed stemflow of dominant beech trees. The study area was at an elevation of 1,180 m in a natural beech forest approximately 30 m high, where the understory vegetation was thinned by deer browsing. Our results were compared with previous studies in coniferous and broadleaf forests.

In the study area, stem flow was estimated at about 13 % of throughfall. The distribution of throughfall was more variable than that in conifer plantation or other broadleaf forests. Compared to coniferous plantations, the structure of the mature beech stand was random. Therefore, in order to obtain a representative throughfall value, it was necessary to do multipoint observations or wide area observations. Wind speed outside of the forest was greater than within the forest. It was suggested that measuring rainfall using tipping bucket rain gages in open mountainous areas results in underestimates because of wind effects. We will also discuss the relationship between wind and stemflow.

Key words: throughfall; stem flow; canopy interception loss; beech forest

[136]

How dose thinning affect the carbon and water balance of a coniferous plantation in subtropical China?

Huimin Wang[1], Mingjie Xu[1], Fengting Yang[1], Xiaoli Fu[1], Xiaoqin Dai[1]

[1]Qianyanzhou Ecological Research Station, Key Laboratory of Ecosystem Network Observation and Modeling, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China

Abstract:

The forested area of China is 208 million ha. Artificial forests account for 36.27% of the total area, but only 16.80% of its mean standing volume. In addition, more than 90% of artificial forests are pure monocultures, threatened by forest pests and diseases. There is an urgent need to optimize the structure of these pure forests for sustainable management.

Broadleaf planting after thinning is one of the most important methods for optimizing the structure of pure forest, and is also the basis for the application of close to natural forest management in future. This option, however, may cause great disturbances in ecosystem function. The short and long-term effects on carbon and water budgets is of great concern.

The eddy covariance method has been used to estimate the effect of thinning ecosystem carbon and water budgets, but large uncertainties exist due to lack of reference sites. In this study, a pair of flux towers (two-tower systems) were used to study variation in carbon and water fluxes after thinning. The effects of thinning on carbon and water budgets of forest plantations were analyzed.

Key words: eddy covariance; carbon and water budget; flux; pure forests; thinning practice

[137] Poster
Plant status controlling the water/energy flux and seasonal variation in isotope composition of evapotranspiration for a temperate grassland ecosystem

Pei Wang [1, 2], Xiaoyan Li [1, 2], Yongmei Huang [1, 2], Wenwu Zhao [1, 2], Ge Sun [3]

[1] State Key Laboratory of Earth Surface Processes and Resource Ecology, Beijing Normal University, Beijing 100875, China
[2] College of Resources Science and Technology, Beijing Normal University, Beijing 100875, China
[3] Eastern Forest Environmental Threat Assessment Center, US Department of Agriculture Forest Service, Southern Research Station, Raleigh, NC27606, U.S.A.

Abstract:

Stable isotopes of water give us useful information for tracing ecosystem processes and, in particular, water vapor sources. They have been extensively used in evapotranspiration (ET) studies. In this study, numerical modelling combined with isotopic measurements of water below and above the land-atmosphere interface was made in a temperate grassland throughout a growing season, to assess change in the relative contribution of transpiration (T/ET) and its relation to vegetation growth. The isotopic composition of ET flux was determined using the "Keeling plot" approach based on water vapor isotope measurements made at three levels. These data were used to calibrate a new numerical Iso-SPAC model (coupled heat and water model with isotopes as a tracer in the Soil-Plant-Atmosphere-Continuum), which was developed and applied to estimate the water/energy flux and isotope composition of ET flux. The agreement between model predictions and observations demonstrates that the Iso-SPAC model under a steady-state assumption for transpiration flux can reproduce seasonal variations in all surface energy fluxes, as well as the isotope composition in ET flux. Sensitivity analysis of both the physical fluxes and isotope composition suggested that T/ET is relatively insensitive to uncertainties/errors in assigned model parameters and measured input variables, which illustrated the partitioning validity. The seasonal change in T/ET could be represented very well by a logarithmic function of leaf area index (determination coefficient equals 0.95), as well as the fraction of latent heat flux to available energy. The seasonal change in the isotope composition of ET flux could also be reproduced well by a nonlinear function of leaf area index with determination coefficient of 0.83. These results demonstrate that vegetation growth affects the water/energy balance and the isotopic budget through transpiration activity, and re-emphasises that an isotope tracer approach is useful for quantitatively evaluating the relationship among them.

Key words: stable isotope; tracer; evapotranspiration; atmospheric water vapor; Iso-SPAC (Soil-Plant-Atmosphere-Continuum with isotopic tracer)

[138]

Assessment of water budget closure for Canada's watersheds

Shusen Wang[1]

[1]Canada Centre for Remote Sensing, Natural Resources Canada, Ottawa, ON, K1A 0E4, Canada

Abstract:

Assessing water budget closure can help us identify knowledge gaps, data quality issues and research needs for better understanding the water cycle and water resources. This study examined water budget closures for 370 watersheds over Canada's landmass by using 30-year (1981-2010) data products recently produced for: precipitation (P) gridded using climate station measurements; land surface evapotranspiration (ET) and water surface evaporation (E0) from the EALCO model; in situ observed streamflow (Q); and total water storage (TWS) from GRACE satellite observations. The selected watersheds include all the watersheds in Canada with Q measurement, having a total area of 3.9 million km^2, or about 39% of Canada's entire landmass. The questions to be addressed are: (1) what are the spatial variations of the water budget for the watersheds across the country?; (2) how well can the water budget be closed?; and (3) what are the possible sources of errors to the water imbalance? Results show that 29%, 58% and 83% of the watersheds were closed within 5%, 10% and 20% of P, respectively. Positive and negative imbalances among the 370 watersheds are largely offset, and the national scale average is -24 mm year^{-1}, or 4.2% of P. Water budget closures have large variation across the country. Regions with sparse or less accurate monitoring of P, such as in the mountains and the Arctic, exhibit the largest water imbalances. Further efforts to enhance the climate observation network in order to improve spatial models for P and ET estimates and streamflow measurements, are all likely critical for a better understanding of Canada's water budgets.

Key words: water budget; watershed; error source; Canada

[139] Poster
Morphological characteristics of solute transport in soils of re-vegetation highway slope by image analysis

Wei Wang[1], Zongwei Chen[1], Dongxu Zhang[2], Tao Liu[1], Lin Chen[1]

[1] China Academy of Transportation Sciences, Beijing, 100029, China
[2] Beijing Forestry University, Beijing, 100083, China

Abstract:

Deicing salts are frequently used to clear highways of surface ice in winter. The salt solution includes sodium, calcium and chloride ions, and can increase soil salinity and inhibit plant growth during transport and accumulation in slope soil profiles. To investigate flow patterns and define the zone affected by deicing salt solution on highway slopes on China's G11 highway in Liaoning province, a stereological analysis method was used. A brilliant blue dye tracer was applied to monitor salt solution movement in a 40 cm depth soil profile on the embankment slope, which was vegetated and built with gravel soil. The morphological parameters of dye coverage (DC) and stained path width (SPW) were calculated using digital image analysis. Results showed that salt movement occurs along preferential flowpaths. Stain in the soil horizons occurred in tiny pores as speckles. Dye coverage in each soil layer decreased with depth. On average, dye coverage in the top 5-10 cm layer was 88.83%, and only 30.74% in the 30-40 cm layer. Based on the stained path width distribution, preferential flow of the salt solution occurred as macropore flow with mixed interaction. Macropores formed in the gravel soil because of variability in grain size distributions and soil density. Soil density in the stained area was 8.6% lower and porosity 197% higher than unstained areas. These results show that preferential flow of a salt solution is determined by soil structure characteristics, and these findings can improve our understanding of water and solute transport in forest and farmland soils.

Key words: preferential flow; image analysis; revegetated highway slopes; solute transport; stained path width

[140] Poster
Ecological problem analysis in the southwest China based on big data environment

Xilin Wang[1], Xili Wang[2]

[1] School of Soil and Water Conservation, Beijing Forestry University, Beijing 100083, China
[2]School of Computer Science, Shaanxi Normal University, Xi'an 710062, Shaanxi, China

Abstract:

Southwest China, including provinces of Sichuan, Chongqing, Yunnan, Guizhou and Tibet, is one of the regions experiencing significant economic development and also ecological transitions. Soil erosion, mudslides, vegetation degradation and desertification are commonly recognized ecological issues in this region. In this study, we first analyzed papers published between 1980 and 2014 focusing on ecological issues in this region. The considered factors include the number of total published papers per year, research topics and study areas. The results indicated that the major ecological problems in Chongqing and Sichuan were mudslides or landslides and hydropower exploitation, while water resource exploitation and dam construction were concerns in Yunnan. In Tibet, climate change and ecological security are the two most frequently mentioned topics. Between 2006 and 2010, the number of papers published on studies in Sichuan was the highest, followed by Chongqing, Yunnan, Guizhou and Tibet, while the number of papers published on Chongqing significantly increased between 2011 and 2014 due to more public concerns over operation of the Three Gorges Reservoir.

Fractional vegetation cover (FVC) in these regions was calculated using remote sensing data in order to analyze vegetation dynamics between 2000 and 2010. FVC maps revealed that some landscapes have experienced vegetation browning, but most landscapes in this region showed no significant vegetation changes. Only small regions in north Tibet, Chongqing, Guizhou and south Sichuan showed certain vegetation greening. Correlation analysis with climate data and socioeconomic factors revealed that temperature played an important role in vegetation distribution. There was a positive correlation between human population and vegetation browning at the provincial level, indicating that heavy population pressure could be a possible predictor or driving factor for regional ecological degradation.

Key words: southwest China; ecology; big data; remote sensing; vegetation

[141]

Variation of evapotranspiration and water yield along forested slopes and the corresponding spatial scale effect in the semiarid Liupan Mountain of NW China

Yanhui Wang[1], Zhenhua Li[1], Xingsheng Han[1], Pengtao Yu[1], Wei Xiong[1], Yanbing Wang[1], Lihong Xu[1]

[1] Institute of Forest Ecology, Environment and Protection, Chinese Academy of Forestry, China

Abstract:

Accurate estimation of water yield reduction after afforestation is essential for guiding integrated forest-water management in dryland regions. Most studies were carried out at either the stand or watershed scale, but there are very few at the slope scale which is the basic spatial unit for understanding and describing forest impacts in distributed hydrological models. Thus, it is necessary to quantify variation of water yield along a slope. In this study, 6 stands with different slope positions (top, upper, middle-upper, middle-lower, lower and foot) were established on two slopes of a *Larix principis-rupprechtii* plantation in semiarid northwestern China. Evapotranspiration (ET) was measured and water yield calculated during the growing season of 2012. Stand ET and water yield varied dramatically along both slopes. ET increased slowly from the slope top to the middle-upper location, then more quickly to the lower position where it reached its maximum and then decreased slightly at the slope foot. ET values were within the range of 218 (408-626) and 116 (422-537) mm on the shaded and semi-shaded slopes, respectively. Water yield generally varied in a contrary manner to ET, within the range of 138 (34-172) and 193 (66-259) mm on the shaded and semi-shaded slopes, respectively. The change rate of the moving average ET and water yield along the horizontal slope length from the top of the slope was used as an indicator of slope scale effect. Change rates were 28.3 and 19.5 mm/100m for ET, and 16.8 and 34.7 mm/100m for water yield on the shaded and semi-shaded slopes, respectively. Statistical relationships between the horizontal distance from the top of the slope and the ratio of stand value to the slope average were fitted. They can be used to estimate the slope average ET and water yield by up-scaling the measured values at any slope position.

Key words: slope scale effect; water yield; evapotranspiration; afforestation; semiarid region

[142] Poster
Partitioning evapotranspiration into evaporation and transpiration in natural shrub land and plantation

Long Wei[1,2,3], Shiping Chen[1], Jiquan Chen[4], Jianhui Huang[1], Xingguo Han[1], Guanghui Lin[5]

[1] State Key Laboratory of Vegetation and Environmental Change, Institute of Botany, Chinese Academy of Sciences, Beijing, China
[2] Graduate University of Chinese Academy of Sciences, Beijing, China
[3] Guangdong Academy of Forestry, Guangzhou, China
[4] Department of Environmental Science, University of Toledo, Toledo, OH, U.S.A.
[5] Ministry of Education Key Laboratory for Earth System Modeling and Center for Earth System Science, Tsinghua University, Beijing, China

Abstract:

The ratio of plant transpiration and soil evaporation to total evapotranspiration (ET) in natural *Artemisia ordosica* shrub land and poplar plantations were determined using the Keeling plot method and stable isotope measurements (δD and δ18O). Keeling plots (vapor turbulent mixing relationships) were generated from isotope ratios of atmospheric water vapor collected within the shrub land and plantation canopies during peak ET (July) and post-monsoon (September) periods of 2006. During the measured period, transpiration accounted for 42.5 to 92% of the ecosystem ET.

Use of the stable isotope technique in combination with the Keeling plot method can partition ecosystem ET measured by eddy covariance into vegetation transpiration and soil evaporation. Ecosystem transpiration in the two communities contributes about 70% of the water loss over a growing season.

The results of this study increase our knowledge on how plants consume water and affect the water balance at a regional scale by understanding the soil-plant-atmosphere continuum. This study also provides scientific information on managing vegetation for desertification prevention.

Key words: ET; flux partitioning; stable isotope; Artemisia ordosica shrub land; poplar plantation

[143]

Clearcut logging effects on water yield at Upper Penticton Creek

Rita Winkler[1], Dave Spittlehouse[1], Sarah Boon[2]

[1]British Columbia Ministry of Forests, Lands and Natural Resource Operations, Kamloops, BC, Canada
[2]Creekside Communication, BC, Canada

Abstract:

Most communities in the Okanagan River Basin, British Columbia, Canada, rely on water derived from mid- to upper elevation snowpacks in forested watersheds. These watersheds also provide timber, recreational opportunities, forage and habitat. Consequently, the effects of clearcut logging on water quantity and timing has long been of interest to resource managers and the public. The Upper Penticton Creek watershed experiment was established in 1984 to quantify hydrologic response to incremental increases in clearcut area across upland watersheds typical of the Okanagan Plateau. Almost 30 years of streamflow record are now available for the three 5 km^2 watersheds within the study area. One watershed has remained forested since the research site was established, and the other two have been logged in approximately 10% increments since 1995, with three or more intervening monitoring periods. Clearcutting resulted in a 12% increase and a 12% decrease in April 1 snow water equivalent at low and high elevations, respectively. Melt season ablation rates averaged 1.2 times greater in the low elevation clearcut than in the forest, but were similar in both the clearcut and forest at high elevation. Snow in the low and high elevation clearcuts disappeared 9 and 13 days earlier than in the forest, respectively. When clearcut-related changes in snow accumulation and ablation occurred over a small area, interannual variability in weather overwhelmed the effects of logging on water yield. As logging extent increased to 50% of total watershed area, variability in daily flows increased, peak flows occurred earlier, and - although changes in total annual yield were small - April/May water yield increased significantly while June/July yield decreased significantly. This paper quantifies water yield response to changes in snow accumulation and ablation associated with increasing clearcut area, a topic of concern in forest development planning and watershed assessments throughout the southern interior of BC.

Key words: long-term forest watershed experiment; logging; water yield

[144] Poster
Study on water balance of *Eucalyptus* plantations in subtropical China

Janping Wu[1], Wenfei Liu[1], Honglang Duan[1], Houbao Fan[1]

[1]Institute of Ecology & Environmental Science, Nanchang Institute of Technology, Nanchang, Jiangxi 330099, China

Abstract:

Anthropogenic activities have destroyed large areas of forests. In subtropical China, these areas are usually reforested with rapidly growing tree species such as *Eucalyptus*. However, the effects of *Eucalyptus* plantations on aspects of the regional water balance remain poorly understood. In age sequences of 2-, 4- and 6-year old *Eucalyptus* plantations, the water consumption, soil evapotranspiration and water balance were examined through a combination of modeling and field monitoring approaches. The main results are as follows: 1) Annual soil evaporation was estimated at 318.6, 336.1 and 248.7 mm for the 2-, 4- and 6-year old stands, respectively. A regression model was developed using soil evaporation, temperature, soil moisture and relative humidity (P=0.0009). 2) Annual canopy evaporation for the *Eucalyptus* plantations were estimated as 558.2, 608.2 and 752.0 mm, which accounted for 31.70%, 34.54% and 42.70% of annual rainfall in the 2-, 4- and 6-year old stands, respectively. 3) Estimated stream flow was 884.0, 816.5 and 760.1 mm for the three stands, respectively, which indicated that discharge decreased with increased plantation age. All results clearly demonstrate that *Eucalyptus* plantations have no significant effect on regional water resources in this abundant precipitation area. However, the effect of high transpiration for *Eucalyptus* will be important as temperature rises in the future. It is proposed that sustainable management strategies for *Eucalyptus* plantations should be implemented to minimize any negative effect on water resources in the context of future climate change scenarios.

Key words: *Eucalyptus* plantation; tree transpiration; stream flow; water balance; water resources

[145]

Development of a distributed eco-hydrological model in the upper Heihe River

Dawen Yang[1], Huimin Lei[1], Bin Gao[2], Hongyi Li[3], Yanlin Zhang[3], Yue Qin

[1]Department of Hydraulic Engineering, Tsinghua University, Beijing 10084, China
[2]School of Water Resources and Environment, China University of Geosciences, Beijing 100083, China
[3]Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China

Abstract:

The Heihe River basin is the second largest inland river basin in China. The upper Heihe River, located in Qinghai-Tibetan Plateau, accounts for 20% of the total basin area and provides 70% of the river flow in the middle and lower reaches. In order to simulate river runoff variation under changes in climate and land use/cover, it is essential to develop a distributed eco-hydrological model. This model uses a 1-km discretized grid system. Furthermore, a 1-km grid is represented by a number of topographically similar "hillslope-valley" systems, and the hillslope is the basic unit of eco-hydrological simulation. Hillslope hydrological processes include glacier/snow melt, canopy interception, evapotranspiration, infiltration, surface flow, subsurface flow and exchange with groundwater. Actual evapotranspiration is calculated by a canopy photosynthesis-conductance model used in SiB2, using satellite data to describe vegetation state and phenology. Infiltration and soil water flow in the vertical direction is simulated using the Richards equation. Surface runoff is calculated from the infiltration excess or saturation excess, and flows through the hillslope into the stream. The groundwater aquifer is treated as an individual storage compartment corresponding to each grid. The exchange between groundwater and the river is calculated by Darcy's law. Flow routing in the river network is solved using the kinematic wave approach.

Based on a 30-year (1983-2012) simulation, it is found that variability in hydrological behavior is closely associated with climatic and landscape conditions, especially vegetation type. Subsurface and groundwater flows dominate the total river runoff. This implies that the process of soil freezing and thawing significantly influences runoff generation in the upper Heihe basin. Furthermore, runoff components and water balance characteristics vary among different vegetation types, showing the importance of coupling the vegetation pattern in catchment hydrological simulations.

Key words: distributed scheme; subgrid parameterization; soil freezing and thawing; canopy photosynthesis-conductance; Heihe River

[146] Poster
Comparison of soil moisture dynamics in two re-vegetation watersheds in semi-arid regions

Lei Yang[1], Liding Chen[1], Wei Wei[1], Yang Yu[1], Handan Zhang[1]

[1]State Key Laboratory of Urban and Regional Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing, 100085, China

Abstract:

Soil moisture is a reliable water resource for plant growth in semi-arid ecosystems. Along with large-scale ecological restoration in the Chinese Loess Plateau, identifying ecohydrological responses to human-introduced vegetation restoration has become an important issue in current research. In this study, the spatial and temporal dynamics of soil moisture were quantified to evaluate the effect of vegetation restoration on soil moisture to a depth of 2 m. Soil moisture at depths of 0-5 m was also obtained by field observation and geostatistical methods in two neighboring re-vegetated watersheds. Profile characteristics and spatial and temporal patterns of soil moisture were compared between different land use types, transects, and watersheds. Results showed that: (1) Soil moisture was drastically decreased by introduced vegetation and became temporally stable when compared with farmland and native grassland. No significant differences in soil moisture content were found between different introduced vegetation types in layers below 2 m. (2) Analysis of differences in soil moisture for different land use patterns indicated that land use had a significant influence on spatial and temporal variability in soil moisture. Land use structure determined the soil moisture condition and its spatial-temporal variation. (3) Vegetation restoration with introduced plants diminished the spatial heterogeneity of soil moisture, and induced temporally stable soil desiccation at the watershed scale. Improved land use management was suggested to improve water management and to maintain sustainability of vegetation restoration.

Key words: soil moisture; spatial variation; temporal dynamics; vegetation restoration; land use structure

[147]

Land cover change trajectories within eastern Taiwan of frequent natural disturbances

Chun-Kuo Yeh[1], Shyue-Cherng Liaw[1]

[1]Department of Geography, National Taiwan Normal University, Taiwan

Abstract:

This study revealed that the Taimali watershed in eastern Taiwan underwent a large-extent land cover change as a result of frequent earthquakes and typhoons during 2005–2011. To demonstrate and grasp the dynamics of land cover change, this study used change trajectory analysis and logistic regression. Change trajectory analysis indicated there were three main trajectories, covering 75.65% of the total changed area, including from forest to landslide (FL), forest to channel (FC), and vegetation recovery (landslide to forest, VR). Based on the cause of the change, most land-cover transformations were found to result from natural disturbances. Therefore, natural forces play a pivotal role in environmental change in the Taimali watershed. Logistic regression analysis showed that lithology is the most important spatial determinant for the three change trajectories. Negative logistic regression coefficients were found for distance to faults and distance to rivers, indicating that the occurrence probability of the three change trajectories decreased with increasing distance to faults and rivers. Three maps of occurrence probability of the change trajectories were produced using the regression coefficients. With validation of the RCI index, the results revealed that the observed change trajectories occurred in zones that had higher probabilities of change and covered a small area. Thus, three spatial statistical models are helpful tools for predicting the occurrence probabilities of the change trajectories.

Key words: change trajectory; logistic regression; probability of change; land cover change; eastern Taiwan

[148]
Runoff change in Jinhe River basin and its causes during last 50 years

Pengtao Yu[1], Yanhui Wang[1], Valentina Krysanova[2], Shaochun Huang[2], Wei Xiong[1], Lihong Xu[1], Haijun Zuo[1], Liangliang He[1]

[1]Research Institute of Forest Ecology, Environment and Protection, Chinese Academy of Forestry, Beijing 100091, China
[2]Potsdam Institute for Climate Impact Research, Potsdam, Germany

Abstract:

Reasons for the dramatic decreases in runoff observed in Northwest China are unclear. A study was initiated in the Jinhe River basin (45,000 km^2), which is located in the Loess Plateau, China. Changes in mean annual temperature, annual pan evapotranspiration and annual precipitation measured at 16 weather stations and 113 rainfall gauges over the period 1960 to 2000 were analyzed using Mann-Kendall tests. Changes in annual runoff were analyzed for 18 station for the same period. It was found that annual temperature increased at the 99% confidence level at all stations, though there was no significant change in annual precipitation and annual pan evapotranspiration. Annual runoff decreased at a rate of 7.2 mm/10 years at the 99% confidence level for the whole basin. This reduction in runoff mainly occurred in the south and southwest parts of the basin. The increase in air temperature accounted for only 20% of total runoff reduction, indicating that land use changes had a greater impact. In the southwest part of the Jinghe River basin, forested area increased about 10 times from the 1960s to 2005. At the same time, although the total area of agriculture decreased by 8%, the area of terraced cropland increased from 3% in 1960 to 69.3% of the total agricultural area in 2006. Runoff reduction due to afforestation and cropland terracing was 113% of annual runoff measured for the Jinghe River basin in 2006. Thus, both climate change and land use change should be seriously considered in order to deal with water shortage in this dry area.

Key words: climate change; runoff; land use change; Loess Plateau

[149] Poster
Carbon and nitrogen in natural oak communities with different climate conditions in northwest China

Jun-Wei Yue[1], Jin-Hong Guan[1], Guo-Qing Li[1], Sheng Du[1]

Institute of Soil and Water Conservation, Chinese Academy of Sciences and Ministry of Water Resources, Yangling, Shaanxi 712100, China

Abstract:

Carbon (C) and nitrogen (N) in above- and below-ground biomass components of natural oak communities were investigated in northwest China. Thirty-two stands at 13 sites were surveyed for analyses of possible relationships between forest C and N, and climate conditions.

The study forests have total C and N densities of 37.072-11.7 t ha^{-1} and 0.51-1.83 t ha^{-1}, respectively, and the concentrations were linearly correlated with an average C/N ratio of 80, though the ratio varied among components. Total C, above- and below-ground C, and below-ground N were positively correlated with annual precipitation, while annual mean temperature was only correlated with below-ground C.

The maximum values of total C and N occurred at sites with mean temperatures of 8.9°C, while maximum below-ground C occurred at the site which recorded the maximum temperature (12.7°C). Maximum N was found at the site where the minimum temperature was recorded (8.1°C). C/N ratios for total and above-ground components changed with precipitation following an n-type curve. Below-ground C/N was positively correlated with temperature. These results may be useful for evaluating climatic limitations to C and N accumulation in natural oak ecosystems.

Key words: forest carbon; nitrogen; oak communities; precipitation; temperature

[150]
Effects of climate change on water and carbon balance in Swedish forest

Giuliana Zanchi[1], Salim Belyazid[2], Cecilia Akselsson[1]

[1]INES, Lund University, Sweden
[2]CEC, Lund University, Sweden

Abstract:

While Swedish forests have the potential of being strong carbon sinks, they also remain huge potential sources if net respiration exceeds sequestration. To investigate if Swedish forest soils will be sinks or sources of carbon by the end of the current century, the integrated forest ecosystem model SAFE was used to simulate the response of forest covers and soil carbon pools at 640 sites in Sweden. The simulations showed that while extremely elevated nitrogen loads could possibly increase carbon sequestration in forest soils, the effect is likely to be cancelled by future climatic changes, particularly during summer droughts.

This study focusses on the effect of future precipitation regimes on forest water and carbon balances. It illustrates how changes in soil moisture, runoff and evapotranspiration caused by climate change could affect forest growth, and thereby tree and soil carbon pools. Different responses of forest ecosystems in different regions in Sweden are also described.

Key words: water balance; carbon balance; climate change; forest modelling; regional scale

[151]

Rainfall partitioning and soil water dynamic under continuous rainfall events in two typical forests in the loess hilly region of China

Jian-Guo Zhang[1], Sheng Du[1]

[1]Institute of Soil and Water Conservation, Chinese Academy of Sciences and Ministry of Water Resources, Yangling, Shaanxi 712100, China

Abstract:

Investigation of rainfall partitioning by vegetation is important for understanding the hydrological cycle and ecosystem function at local and catchment scales. In this study, throughfall, stemflow, runoff and soil water dynamics were measured for three land use types (*Quercus liaotungensis* forest (QF), *Robinia pseudoacacia* plantation (RP) and bare land (BL)) during a period with continuous rainfall events. Results showed that throughfall was linearly correlated with gross rainfall, and accounted for 86% and 89% of gross rainfall in QF and RP, respectively. Positive correlation between stemflow of individual trees and DBH was observed in QF but not in RP. The proportion of stemflow in gross rainfall at the stand scale was 14% (QF) and 6% (RP) for the two forests. There were significant quadratic relationships between runoff and gross rainfall in all land use types. Soil water storage increased by 287mm (QF), 227 mm (RP) and 258 mm (BL) during the study period, and accounted for 61.5% (QF), 48.7% (RP) and 55.3% (BL) of gross rainfall. Net rainfall (stemflow + throughfall) was consistent with gross rainfall in QF, and canopy interception was approximately zero during continuous rainfall events in this forest. Net rainfall was less than gross rainfall in RP, and the difference between them might be associated with redistribution by shrubs. The results may be useful for evaluation of ecosystem service of these vegetation types.

Key words: continuous rainfall; stemflow; throughfall; runoff; soil water dynamic; *Quercus liaotungensis*; *Robinia pseudoacacia*

[152]

Responses of streamflow to anthropogenic impacts in catchments with different landform features on the Loess Plateau, China

Jianjun Zhang[1, 2], Tingting Zhang[3], Lili Chen[3], Pengfei Lin[1], Xiaoping Zhang[1], Yipeng Yu

[1]State Key Laboratory of Soil Erosion and Dry Land Farming on the Loess Plateau, Institute of Soil and Water Conservation, Chinese Academy of Sciences and Ministry of Water Resources, Yangling, Shaanxi, 712100, China
[2]University of Chinese Academy of Sciences, Beijing, 100049, China;
[3]Resource and Environment College, Northwest A & F University, Yangling, Shaanxi, 712100, China

Abstract:

The loess hilly-gully (LHG) and table-gully (LTG) areas are two main landforms on the Loess Plateau. To control severe soil erosion, numerous soil conservation measures were implemented after the 1970s, as well as the national "Grain for Green" project beginning in 1999. Many studies showed streamflow decreased in plateau catchments due to the conservation measures. However, it is not clear how streamflow regimes in the different landforms were affected. Six nested catchments were selected in LHG, LTG and the loess hilly forestry (LHF) areas with good quality secondary-growth forest cover. Daily streamflow data from 1958 to 2011 were used, and M-K trend tests and Flow Duration Curves were used to detect trends and changes to streamflow regimes. Results showed a statistically significant negative trend in annual streamflow for catchments in both LHG and LTG, with rates varying from -0.11 to -0.51 mm/a. No significant trend was found in LHF. Change point years occurred around 1979 and 2000 in LHG and LTG, respectively. Changes in high (5% exceedance) and median flow (50%) were consistent in all catchments, showing a decreasing trend. Implementation of integrated soil conservation measures in the 1970s first resulted in an increase in low flow (95%) from 1980 to 1999. Catchments responded differently after 1999 and implementation of the "Grain for Green" project. In the LHG, where grass and shrub were the dominant vegetation types, low flow continuously increased, and in the LTG, dominated by arbor and shrub, low flow decreased. In general, streamflow in the LHF was the most stable, followed by the LTG and the LHG. Anthropogenic impacts were found to be the main factor explaining streamflow decrease in the study area, but ecological factors dominated changes to streamflow regime. This finding is helpful for regional landuse planning and sustainable ecosystem management on the Loess Plateau.

Key words: streamflow; streamflow regime; soil conservation measures; "Grain for Green" project; landforms; Loess Plateau

[153]

The hydrological responses to cumulative forest disturbances in six large watersheds, B.C. Interior, Canada

Mingfang Zhang[1], Adam Wei[2]

[1]University of Electronic Science and Technology of China, China
[2]University of British Columbia, Kelowna, British Columbia, Canada

Abstract:

Six large watersheds experiencing various levels of forest disturbance along environmental gradients in the BC interior (Willow River, Cottonwood River, Baker Creek, Moffat Creek, Tulameen River, and Ashnola River watersheds) were selected to assess hydrological responses to forest disturbances. Cumulative equivalent clear-cut area (CECA) was used to indicate cumulative forest disturbance. A novel method combining advanced statistical methods (e.g. time series analysis) with graphical methods (modified double mass curve and flow duration curve) was employed to conduct statistical and quantitative assessments. Results show that forest disturbances had significant impacts on annual mean flows and some seasonal mean flow indices in the intensively disturbed watersheds, including the Willow River, Baker River, Moffat Creek, and Tulameen River watersheds. Comparisons suggest that wetter years and wetter watersheds were more sensitive to forest disturbances compared with drier years and drier watersheds.

Key words: forest disturbances; hydrology; BC Interior; CECA

[154]

Responses of baseflow to the vegetation restoration in a catchment, Loess Plateau of China.

Xiaoping Zhang[1],Yipeng Yu[2], Tingting Zhang[2], Jianjun Zhang[1]

[1]State Key Laboratory of Soil Erosion and Dry Land Farming on the Loess Plateau, Institute of Soil and Water Conservation, Chinese Academy of Sciences and Ministry of Water Resources, Yangling, Shaanxi, 712100, China
[2]Resource and Environment College, Northwest A & F University, Yangling, Shaanxi, 712100, China

Abstract:

Baseflow is an essential part of runoff during the dry season on the Loess plateau, China. Its variability is an important hydrological characteristic in maintaining ecosystem health and water security. In last 50 years, vegetation gradually increased on the Loess Plateau, especially after the "Grain for Green" project was implemented in the 1990s. However, it is not clear how the vegetation cover change influenced baseflow in the area. Daily streamflow data over the period 1959 to 2011 at the Wuqi, Zhidan and Liujiahe catchments of the Beiluo river basin were used to analyze the responses of baseflow to land cover change. Results showed that mean annual baseflow at the three gauge stations were 9.3, 10.1 and 12.7mm, respectively, which accounted for 34.5, 26.9 and 40.0% of total runoff, respectively. Statistically significant ($p<0.005$) positive trends in baseflow were detected at both the Wuqi and Liujiahe stations. Mean annual change rates in each station were 0.046 and 0.058 mm a^{-1}, and accounted for nearly 0.5% of total baseflow from the two stations. Compared to 1959-1979 (P1), the baseflow in 1980-1999 (P2) increased by 9.1 and 20.5% at the two stations. In 2000-2011 (P3), baseflow changed by 14.5 and 8.6% respectively. A non-statistically significant decreasing trend was found at the Zhidan station. Baseflow indices (BFI) at all three stations showed statistically significant ($p<0.005$) increasing trends over the period of record. Compared to P1, BFI at three stations during P2 increased 15-25%, while during P3 BFI increased 70-110%. It was found that, in general, every 10% increase in vegetation cover resulted in a 0.76mm increase in baseflow or 0.158 increase in BFI in the study area.

Key words: baseflow; BFI; vegetation restoration; catchment; Loess Plateau

[155]

Effect of forest changes on runoff and sediment in Dongjiang watershed

Ping Zhou[1], Zhiyong Liu[2], Changjun Gao[1], Long Wei[1], Gang Chen[1], Xiuzhi Chen[3]

[1]Institute of Geography, Heidelberg University, Heidelberg D-69120, Germany
[2]Department of Forest Ecology, Guangdong Academy of Forestry, Guangzhou 510520, China
[3]South China Botanical Garden, Chinese Academy of Sciences, Guangzhou, 510650, China

Abstract:

The hydrological effect of forest changes varies globally. In subtropical regions, understanding how forest changes affect water resources and sediment is important to sustainable water management, soil and water conservation and afforestation. In this study, we analyzed 22 years of hydrological data from upper and lower reaches of the Dongjiang watershed, South China, during forest restoration. Time series analysis with Mann-Kendall statistical testing were used with long term data on vegetation cover changes based on satellite images. Our results showed that there was no significant reduction in runoff as a result of forest restoration from an area of 12,553 km^2 in 1989 to 16,020 km^2 in 2009. However, sediment declined significantly ($P < 0.01$) in both dry and wet seasons. It implied that forest recovery contributed to soil erosion control and did not cause a reduction of water resources in this subtropical region.

Key words: Dongjiang watersheds; forest restoration; runoff; time series analysis; subtropical region

[156]

Effects of forest types in headstream region of Hun-River on water quality of outlets from forested catchments, northeast China

Jiao-jun Zhu[1, 2*], Tian-le Xu[1, 2], Li-zhong Yu[1, 2], Xingyuan He[1, 2], Xiu-Fen Li[2, 3], Kai-yang Yang[1, 2]

[1]State Key Laboratory of Forest and Soil Ecology, Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang 110164, China
[2]Qingyuan Forest CERN, Chinese Academy of Sciences, Shenyang 110016, China
[3]Shenyang Agricultural University, Shenyang 110866, China

Abstract:

Forests play a critical role in conserving water in the headstreams of rivers and reservoirs. Plantation forests have replaced many of the mixed broadleaf secondary forests (SF) in the headstream regions of the Hun River, northeast China. In order to explore the effect of forest type on water quality, we compared two catchments, one dominated by SF (2.42 ha) and the other by Korean pine (*Pinus koraensis*, the regional dominant tree species) plantations (KP) (2.46 ha). Physical (COND, TURB, TDS, DO) and chemical (pH, Cl^-, NO_3^--N, NH_4^+-N, TP) properties of streamwater, rainfall, throughfall, stemflow, and flow through the litter layer were monitored in the two catchments. Compared to rainfall, the physical water quality decreased significantly after flowing through the forests. The pH of streamwater for both SF and KP significantly decreased from 6.38 (rainfall) to 5.87 (SF) and 5.75 (KP). The concentrations of Cl^- and NH_4^+-N in streamwater were not significantly higher than those measured in rainfall because the soil can adsorb or desorb Cl^- and NH_4^+-N effectively. TP concentration in the streamwater of the SF catchment was significantly higher than in both rainfall and streamwater from the KP catchment because phosphorus in the litter and soil of the SF catchment was higher than that in the KP catchment. However, the NO_3^--N concentration in streamwater from the KP catchment was significantly higher than that in rainfall and outlet water from SF catchment, because NO_3^--N was easily leached in the KP catchment. In summary, although rainfall acidified after flowing through the forests, there was no significant difference between SF and KP forested catchments in influencing water quality. This suggests that there may be an appropriate ratio of KP plantations that can be established within secondary forest systems to facilitate forest recovery in headstream regions.

Key words: forested catchments; secondary forest; plantation forest; disturbance; water quality

[157]

Carbon balance in the forested boreal landscape: The significance of the aquatic conduit in a variable climate

Kevin Bishop[1,2], Audrey Campeau[2], Hjalmar Laudon[1], Fraser Leith[2], Marcus Wallin[2], Mats Öqvist[1]

[1]Swedish University of Agricultural Sciences and Uppsala University, Sweden
[2]Uppsala University, Sweden

Abstract:

Boreal forests are important ecosystems for global C cycling, and they play an integral role in the source/sink dynamics of atmospheric CO_2. During the last decade, the exchange of CO_2 between boreal forest soils and the atmosphere has been intensely studied, which has established a substantial data set for the vertical exchange of CO_2. However, much less attention has been directed towards surface waters in the boreal landscape and how the lateral flux of C from these systems functions with respect to the total C balance of boreal forest ecosystems. In particular, the lateral export of e.g. CO_2 from soils to aquatic conduits, and its concomitant downstream transport and/or emission to the atmosphere, has received little attention, despite the fact that the few studies that have attempted to quantify these processes show that they are potentially important for the net C balance in several types of ecosystems.

This presentation will elucidate the relative importance of lateral DIC export on total C budgets of the boreal landscape, and the sensitivity of export to changes in runoff and stream discharge. This is achieved by validating a model of lateral C flux against independent data, then using this model to predict annual and inter-annual variations in the export of DIC and DOC. This will then be compared to interannual variations in net ecosystem productivity (NEP) in the area. A major finding from this investigation is an inverse co-variation between annual C export across the soil/stream interface (lateral export of C) and vertical C dynamics (NEE) of terrestrial forest ecosystems. Wet years have more lateral C export and less vertical C accumulation, and vice versa. Forest ecosystems also appears more dynamic than mire ecosystems with regards to interannual variation in NEE.

Key words: forests; DIC; DOC; net ecosystem exchange; inter-annual variability

[158] Poster
Relating forest plantation growth to LiDAR-DEM determined variations in soil condition

Mark Castonguay, Shane Furze, Marie-France Jones, Jae Ogilvie, Paul A. Arp

Forest Watershed Research Centre, Faculty of Forestry and Environmental Management, University of New Brunswick, Fredericton, New Brunswick, Canada

Abstract:

Within forest plantations, as with other crops requiring well-drained soils, topographic variations have a strong influence on within-field productivity. Productivity is generally low to absent in poorly to very poorly drained areas, and weakened on drought-prone soil such as along ridges and steep slopes. This poster demonstrates that these variations can now be mapped (at least in part) using LiDAR-generated bare-earth digital elevation models (DEMs) and using the cartographic depth-to-water index (DTW) to emulate soil type, drainage and properties related to depth, density, texture, organic matter content and other parameters. This poster focusses on a 250,000 ha industrial plantation study area in northern New Brunswick.

Key words: forest plantation; soil productivity; height growth; digital elevation modelling; LiDAR

[159] Poster
Soil moisture regime preferences of forest vegetation, mapped at high resolution

Monique Goguen, Douglas Hiltz, Jae Ogilvie, Paul A. Arp

Forest Watershed Research Centre, Faculty of Forestry and Environmental Management, University of New Brunswick, Fredericton, New Brunswick, Canada

Abstract:

This poster summarizes how soil moisture regime preferences can be mapped using LiDAR-derived bar-earth digital elevation models (DEMs). This is done by hydro-conditioning these DEMs to ensure that the resulting DEM-derived flow accumulation, stream network and soil wetness (i.e. cartographic depth-to-water DTW) patterns conform to already mapped surface water features. Plot-based vegetation surveys across the targeted areas are then used to determine how species presence/absence and abundance per plot relate to DTW and also to the DEM-derived terrain wetness index (TWI). We also determined the soil moisture regime preference vegetation index (VI) for each plot. This index ranges from xeric (0) to mesic (4) and hydric (8). The VI values compare well with DTW but not with TWI. Looking at moss species specifically revealed that the probability of moss occurrence varies by species type, DTW and other factors such as leaf litter thickness, canopy closure and forest type. Conducting these surveys over variable terrain and climate conditions across Alberta and New Brunswick suggests that the approach used is generally valid and numerically robust.

Key words: soil moisture regimes; vegetation index; digital elevation modelling; LiDAR; depth-to-water index

[160]
Increasing in watershed runoff by the management practice of devastated forest plantation in Japan

Yuichi Onda[1], Takashi Gomi[2], Xinchao Sun[3], Hirokazu Haga[4], Maki Tsujimura[3], Kyoichi Otsuki[5], Kazukiyo Yamamoto[6]

[1]Center for Research in Isotope and Environmental Dynamics, University of Tsukuba, Japan
[2]Department of International Environmental and Agricultural Science, Tokyo University of Agriculture and Technology, Japan
[3]Faculty of Life and Environmental Sciences, University of Tsukuba, Tsukuba, Ibaraki, Japan
[4]Faculty of Agriculture, Tottori University, Tottori, Japan
[5]Kasuya Research Forest, Kyushu University, Fukuoka, Japan
[6]Graduate School of Bioagricultural Sciences, Nagoya University, Nagoya, Japan

Abstract:

Sixty-five percent of Japan's land area is forested, more than 40% of which are Japanese cedar and cypress plantations. We conducted intensive field observations during catchment-scale manipulation of five watersheds covered by Japanese cedar and Japanese cypress plantations. Runoff has been monitored continuously for the last nine years at three watersheds in Aichi, Mie and Kochi, and since 2009 in Tochigi and Fukuoka. Catchment runoff, sediment yield and a variety of hydrological processes were monitored continuously for five years, including pre- and post-thinning treatment (50% stem removal). Changes pre- and post-thinning are examined for rainfall, throughfall, evaporation, soil moisture, groundwater, Hortonian overland flow and stream runoff, and water chemistry and stable isotopes were measured during both low and high flows. Soil erosion at the hillslope scale and suspended sediment discharge at the watershed scale were also monitored. Thinning reduced canopy interception and evapotranspiration. Field-based monitoring was combined with remote sensing techniques to develop integrated models for adaptive forest management at the catchment scale.

Key words: forest management; planation forest; thinning practices; baseflow; watershed-scale experiment

[161]

The digital landscape of watershed analysis at large spatial scales

Michael Wagner[1], Faye Hirshfield[2], Axel Anderson[3], John Diiwu[4], Lee Benda[5]

[1]Alberta Environment and Sustainable Resource Development, Calgary, Alberta, Canada
[2]University of Alberta, Edmonton, Alberta, Canada
[3]Foothills Research Institute, Edmonton, Alberta, Canada
[4]Alberta Environment and Sustainable Resource Development, Edmonton, Alberta, Canada
[5]Earth Systems Institute, Mt. Shasta, CA, USA

Abstract:

Forested watersheds in the province of Alberta provide approximately 88% of surface water supplied to urban and municipal communities and are home to many endangered or threatened aquatic species. Increasing human (e.g. petrochemical, forestry, agriculture, recreation) and natural (wildfire, insects) disturbance within these source water regions has emphasized the need to develop multi-level watershed assessment protocols based on cumulative effects. Significant challenges in the development of watershed assessment protocols are the quantification of linkages between terrestrial and/or in-stream disturbances to watershed processes, and the alteration and propagation of cumulative effects downstream. These challenges are accentuated when attempting to quantify risk at multiple spatial scales (cutblock → stream reach → watershed) and across variable hydro-climatic conditions. This collaborative project focuses on testing a spatial watershed assessment tool to enable better understanding of linkages between human caused land-use and hydro-ecological processes based on a cumulative effects framework and stream routing.

A case study is presented demonstrating how an innovative GIS based tool (NetMap), developed by Earth Systems Institute for resource management and conservation in the Pacific Northwest, can improve understanding of land use/watershed/aquatic ecology interactions at large spatial scales. These tools were tested in the headwaters of the Oldman River basin in southwestern Alberta. NetMap provides rapid identification of areas where more conventional (i.e. field based) watershed assessments are required, in order to maximize use of public resources in addressing watershed management and remediation efforts, while simultaneously providing an interactive platform for public education, engagement and consultation.

Key words: assessment; cumulative effects; watershed; modelling

Authors Index

NB: For consistency, all authors are listed by the last name of their family name. Bolded items indicate first authorship.

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